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Articles

Measuring Producers' Advantage from Classified Pricing of Milk

Dae Hee Song and M. C. Hallberg

A method of assessing the degree to which classified pricing of milk has favored milk producers over time is outlined, and results of an application of this method to the 1960–79 period are presented. It is found that prices for the different use classes of milk have, over this period, moved closer to consumer "optimal" prices rather than to producer "optimal" prices. Apparently the regulatory authorities in recent years have recognized less the need for farm income enhancement than the voice of consumer representatives.

Key words: classified pricing, dairy policy, price discrimination.

In recent years the federal milk-marketing order program and the dairy price support program have been severely criticized for causing substantial welfare losses and transfers of income from consumers to producers (Ippolito and Masson, Masson and Eisenstat). Recent empirical work by Dahlgran and Buxton lends strong support to this argument. Dahlgran estimated the social cost (deadweight losses plus costs of program administration) of these programs in 1976 to have been \$131 million—slightly over 1% of the cash receipts from farm marketings of dairy products. Dahlgran also estimated substantial income transfers as a result of these programs—\$439 million from fluid milk consumers to grade A milk producers, \$366 million from grade A milk producers to manufactured dairy product consumers, and \$200 million from grade B milk producers to manufactured dairy product consumers. Buxton, using a similar approach but a much less complex model, estimated the social costs of alternative federal order minimum Class I price differentials. Buxton held the impact of the dairy price support program constant; hence, his social cost estimates were much smaller than Dahlgran's. Buxton concluded that the implied transfer payments caused by higher Class I differentials were far more significant than the social costs caused by higher Class I differentials.

A major concern of dairy program critics revolves around the extent to which these programs have advantaged producers at the expense of consumers. The studies mentioned appear to justify this concern although each relates to a single year. In this paper we attempt to assess more precisely the extent to which milk producers have been so advantaged. We do so for each year of the 1960–79 period in order to establish the existence of some trend in producer advantage.

The Conceptual Model

To accomplish the objective of this paper, we estimate for each of the past twenty years, conditional upon the actual amount of milk available for processing in each year, (*a*) a set of prices for the various use classes of milk that would have maximized consumer welfare from consumption of this milk, and (*b*) a set of prices of the various use classes of milk that would have maximized milk producers' aggregate gross income. Actual prices and actual gross income are compared with the prices and gross income generated from these two solutions to assess the extent to which producers were advantaged by the dairy programs in each of the twenty years.

We do not imply here that the two "optimal" solutions generated would have been ob-

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served in the real world had the regulatory authorities actually set out to maximize consumer welfare or to maximize producers' gross income. Clearly the solutions generated here likely would not have occurred under the conditions specified because producers, upon learning that the rules of the game had changed, would respond by producing either less or more milk. For example, in a perfectly competitive world, where consumer welfare maximizing prices occur, grade A milk producers, producing in excess of the market's grade A needs, would be forced by the market to respond to the marginal value of that surplus milk rather than to the higher blend or average value to which they now respond under federal orders. Hence, we would expect a reduction in aggregate milk production.

On the contrary, our objectives are less ambitious. The question we address is, given the amount of milk actually produced in a given year, did the regulations in effect cause actual milk prices in that year to be set at levels consistent with those of either of the two extremes or somewhere in between? Hence, the two "optimal" solutions to be generated are useful only for making this comparison.

Maximization of Producer Income

Suppose we have n use classes of milk and suppose that for each use class the annual farm level demand function can be written

$$Q_i = a_i + \Sigma_j b_{ij} P_j, \tag{1}$$

where $i, j = 1, 2, \ldots, n$; Q_i represents consumer demand for milk used in the ith use class; and P_j represents the farm price of milk used in the jth use class.

Given the above demand functions, the price-quantity combinations that will maximize aggregate producer gross income can be found by solving the quadratic programming problem:

$$\text{maximize } R = \Sigma_i P_i Q_i = \Sigma_i P_i (a_i + \Sigma_j b_{ij} P_j), \tag{2}$$

subject to

$$a_i + \Sigma_j b_{ij} P_j = Q_i \qquad \text{for all } i, \tag{3}$$

$$\Sigma_i Q_i = TQ, \tag{4}$$

$$P_i,\ Q_i \geq 0 \text{ for all } i. \tag{5}$$

If the solution to this problem yields positive prices and quantities, then it is easily shown by solving the Lagrangian problem that marginal revenues in all markets are equal.

Maximization of Consumer Welfare

Maximum consumer welfare is here defined as the maximum utility accruing to consumers from consumption of all use classes of milk. Hence, given the demand functions defined by equation set (1), the price-quantity combinations that will maximize consumer welfare can be found by solving the problem:[1]

$$\text{Max } U = \Sigma_i \int_0^{Q_i} (A_i + \Sigma_j B_{ij} Q_j) dQ_i, \tag{6}$$

subject to

$$A_i + \Sigma_j B_{ij} Q_j = P_i \tag{7}$$

for all i,

$$\Sigma_i Q_i = TQ, \tag{8}$$

$$P_i,\ Q_i \geq 0, \tag{9}$$

where the functions, $A_i + \Sigma_j B_{ij} Q_j$, in equation (6) are price-dependent demand functions derived from equation set (1). If the solution to this problem yields positive prices and quantities, then it is easily shown by integrating and solving the Lagrangian problem that prices in all markets must be equal.

Model Specification and Generation of Optimal Solutions

For this study, six different uses of milk were considered—butter, cheese, evaporated milk, fluid milk products, frozen products, and other dairy products. The various uses of milk were assumed to constitute separate markets, but the demand for one use class was assumed to be a function of its own price as well as the prices of all other uses. Thus, the farm-level demand functions were specified as

$$Q_{it} = a_{it} + \sum_{j=1}^{6} b_{ijt} P_{jt}, \tag{10}$$

where $i, j = 1, 2, \ldots, 6$; $t = 1, 2, \ldots, T$; Q_{it} represents the quantity of fluid milk equivalent (on a butterfat basis) used in the ith use class in year t; and p_{jt} represents the farm price of milk used in the jth use class in year t.

---

[1] Whether or not this is the solution that will actually maximize consumer welfare (or, more appropriately, consumer utility) is debatable. It is, nevertheless, the nondiscriminatory, competitive solution.

Uchtmann, Donald L., J. W. Looney, N. G. P. Krausz, and H. W. Hannah. *Agricultural Law: Principles and Cases/Philip E. Harris*/169

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The Q_{it} were derived by subtracting net exports, net additions to government and private stocks, and military consumption from milk utilized in each class. This captures the purely commercial component of the domestic dairy market. The "effective buying price" of fluid milk (the price paid by handlers for fluid grade milk including any overorder premiums) was taken as the price of fluid milk products (P_{4t}); the Class II price in the Chicago Regional Federal Milk Marketing Order was taken as the price of milk used in frozen products (P_{5t}); and the price of milk used in other products (P_{6t}) is the price for that product most frequently having the lowest value—evaporated milk. Data regularly published by USDA on the price of milk used in butter, cheese, and evaporated milk was used for the price of the remaining use classes.

Own and cross-price elasticities shown in table 1 were taken or derived from George and King and from Brandow. These constant elasticity coefficients were converted into the linear slope coefficients of equation set (10) consistent with each year's actual price/quantity ratio. The intercepts of equation set (10) were then derived so that each year's actual price-quantity point would lie on the linear demand function for that year.

Solutions to the revenue maximization problem for each of the years 1960 through 1979 were obtained with a quadratic programming algorithm much like that of Ladd and Updegraff. These solutions were checked for realism by comparing the solution quantity levels with minimum consumption levels estimated from the 1965 USDA Food Consumption Survey (USDA). Based on this comparison the solution quantity levels appeared quite reasonable. Only in the case of evaporated milk did the solution quantity levels fall below the estimated minimum for some years, but never by more than 2%.

The consumer welfare maximization model as specified above must be modified to reflect the fact that milk used for fluid products is subject to higher quality standards and thus is more costly to produce than is milk used for manufactured products. Although the magnitude of this cost differential is subject to considerable debate, Frank, Peterson, and Hughes provide an estimate of 27¢/cwt for the year 1974. Accordingly, we constrained the model so that the price of milk used for fluid products would be 3% higher than the price of milk used for other products to approximate a differential of 27¢/cwt in 1974.

It is frequently argued that, given the structure of the dairy industry today, a higher differential between the two types of milk is justified on the basis of additional and legitimate marketing services provided by cooperatives. The above model, however, is predicated on the assumption that the industry will, as a result of the forces of competition (or as a result of regulatory action), make plant location and behavioral decisions consistent with maintenance of the specified equilibrium prices. Hence, under the conditions of the model, no basis exists for a price differential in excess of the cost of production differential.[2]

Empirical Results

Actual and "optimal" values of prices, quantities, and gross farm income for selected years are shown in tables 2, 3, and 4. The results indicate that producers' gross income could have been increased in each of these

Table 1. Matrix of Price Elasticities at the Farm Level

	Butter	Cheese	Evaporated Milk	Fluid Milk	Frozen Products	Other
Butter	−.46086	.00153	.000386	.00678	.00105	0
Cheese	.00084	−.35214	−.00006	.00117	.00473	0
Evaporated milk	.00166	.00095	−.28090	.20127	.00065	0
Fluid milk	.00099	.00052	.00883	−.32395	.00035	0
Frozen products	.00056	.00554	−.00016	−.00086	−.45114	0
Other	0	0	0	0	0	−.36600

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[2] As pointed out by an anonymous referee, the prices used in this study are FOB plant prices. Hence, our differential between fluid and manufacturing milk prices also should reflect the difference, if any, between the cost of transporting fluid and the cost of transporting manufacturing milk to processing plants. It is conceivable that a positive transportation differential would exist under the competitive conditions of the model specified. We are aware of no studies which have established the level of this differential even under existing conditions. In general, however, we see little reason to argue that this differential would be large enough in the aggregate to have any perceptible impact on the conclusion of this study.

Table 2. Actual and "Optimal" Prices in Cents per Hundredweight, 1960–79

Year	Butter	Cheese	Evaporated Milk	Fluid Products	Frozen Products	Other Uses	Weighted Average
				Actual Prices			
1960	302	308	305	548	315	305	421
1965	322	318	313	536	333	313	423
1970	452	461	428	693	466	428	565
1975	754	758	733	995	772	733	866
1979	1,071	1,085	1,054	1,332	1,101	1,054	1,185
				"Optimal" Producer Prices			
1960	144	266	691	830	181	230	458
1965	166	272	739	792	200	234	456
1970	246	417	1,141	994	292	320	602
1975	446	705	1,982	1,352	513	604	907
1979	665	1,044	3,038	1,778	775	913	1,233
				"Optimal" Consumer Prices			
1960	368	368	379	379	379	368	375
1965	380	380	391	391	391	380	387
1970	521	521	538	538	538	521	531
1975	826	826	851	851	851	826	841
1979	1,145	1,145	1,181	1,181	1,181	1,145	1,164

Note: The actual and "optimal" prices were recorded or calculated for all of the twenty years as is indicated in figures 1–6.

years by a reallocation of the milk actually produced among the six use classes under a more discriminatory pricing scheme. This increase would have been possible had more milk been marketed in the butter, cheese, frozen products, and other dairy product markets at lower prices, and less milk marketed in the fluid market at higher prices. These results are, of course, consistent with the elasticities assumed here—demand elasticities for butter, cheese, frozen products, and other dairy products are slightly higher than that for fluid milk.

On the other hand, had milk been priced to maximize consumer welfare, gross farm income would have been lower in each of the years indicated. This would have happened because of a decrease in price and an increase in the quantity of milk used in fluid products, and by an increase in price and a decrease in quantity of milk used in all other products. These results are in line with the relative de-

Table 3. Actual and "Optimal" Quantities in Millions of Pounds, 1960–79

Year	Butter	Cheese	Evaporated Milk	Fluid Products	Frozen Products	Other Products	Total
				Actual Quantities			
1960	30,696	13,219	5,012	58,500	9,186	6,496	123,109
1965	29,020	16,695	4,324	58,843	10,312	4,987	124,181
1970	24,155	21,476	2,896	54,176	10,816	3,488	117,007
1975	20,023	26,577	2,433	52,478	11,694	2,129	115,334
1979	19,500	32,396	2,019	51,521	11,533	6,654	123,623
				"Optimal" Producer Quantities			
1960	38,178	13,834	3,743	49,342	10,930	7,082	123,109
1965	35,591	17.518	3,083	50,389	12,154	5,446	124,181
1970	29,303	22,156	1,791	47,323	12,625	3,810	117,007
1975	23,845	27,190	1,442	47,143	13,448	2,266	115,334
1979	22,957	32,779	1,086	46,762	13,060	6,978	123,623
				"Optimal" Consumer Quantities			
1960	27,570	12,326	4,362	64,488	8,355	6,007	123,109
1965	26,587	15,565	3,787	64,134	9,510	4,598	124,181
1970	22,418	20,496	2,558	58,249	10,077	3,209	117,007
1975	19,129	25.749	2,253	55,015	11,159	2,030	115,334
1979	18,866	31,770	1,905	53,478	11,161	6,443	123,623

mand elasticities for the various dairy products.

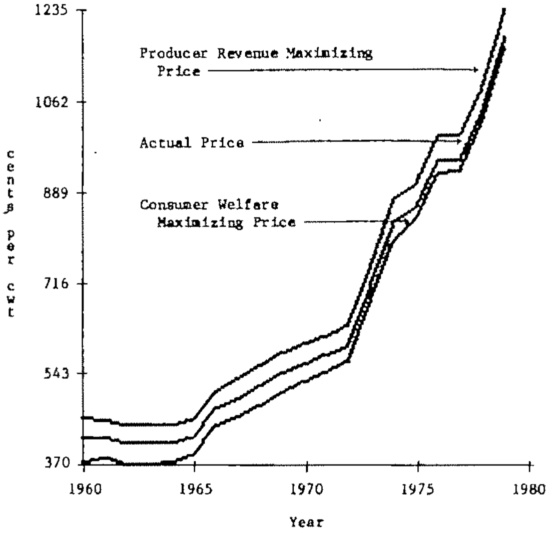
Of perhaps greater interest and importance is the relation of actual prices of milk used in the various dairy products and the weighted average price of milk to the two extreme sets of prices. This relation can be inferred for each of the six use classes from the data in tables 2 and 3. Figures 1 and 2 show this relation somewhat clearer for the weighted average price and for the price of milk used in selected products.

Some rather striking conclusions are revealed by these comparisons. First, the window between the weighted average price for producer revenue maximization and that for consumer welfare maximization is relatively small (less than $1.00/cwt). It has become progressively smaller over the twenty-year period (from 83¢/cwt in 1960 to 69¢/cwt in 1979). Second, the actual weighted average price, while slightly closer in 1960 to that price which would have maximized producer welfare, has since then moved progressively closer to that price which would have maximized consumer welfare, figure 1. In 1979, the actual weighted average price was only 21¢/cwt above that price at which consumer welfare would have been maximized, but 48¢/cwt below that price at which producer welfare would have been maximized.

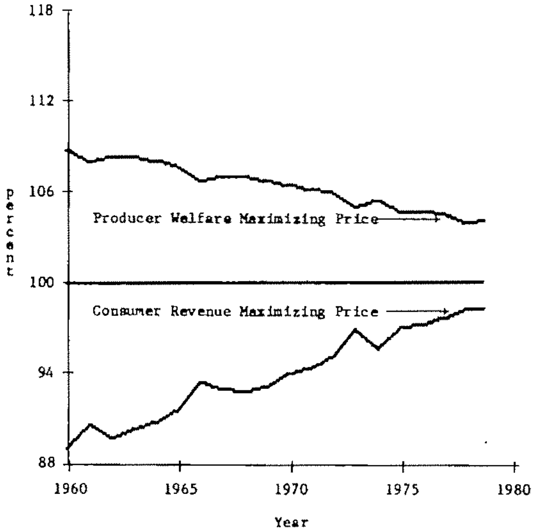
Since the extreme prices were determined subject to the restriction that the total annual quantity of milk marketed in each solution equals the actual quantity marketed, the above statements also apply to producer revenue. The columns of table 4 showing producer revenue under the two optimization schemes as a percentage of actual producer revenue puts this idea into clearer perspective.

Table 4. Producer Gross Revenue from the Sale of Milk under Producer Revenue Maximization and under Consumer Welfare Maximization, 1960–79

	Under Producer Revenue Maximization		Under Consumer Welfare Maximization	
Year	$ Million	% Deviation from Actual	$ Million	% Deviation from Actual
1960	5,636	8.8	4,615	−10.9
1965	5,658	7.7	4,806	−8.5
1970	7,042	6.5	6,216	−6.0
1975	10,153	4.8	9,210	−2.8
1979	15,243	4.1	14,394	−1.7



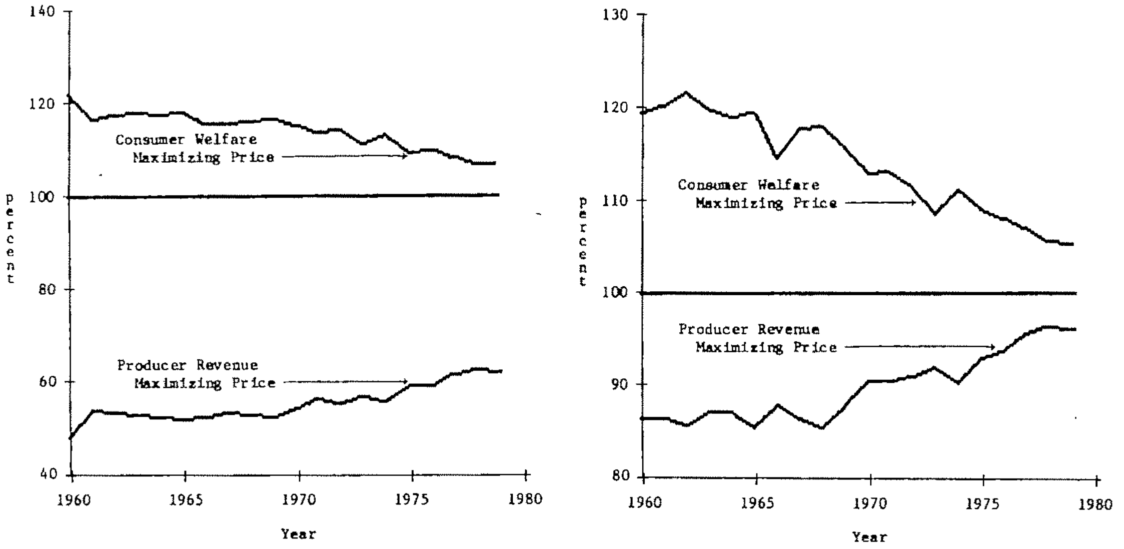
"Optimal" and actual prices



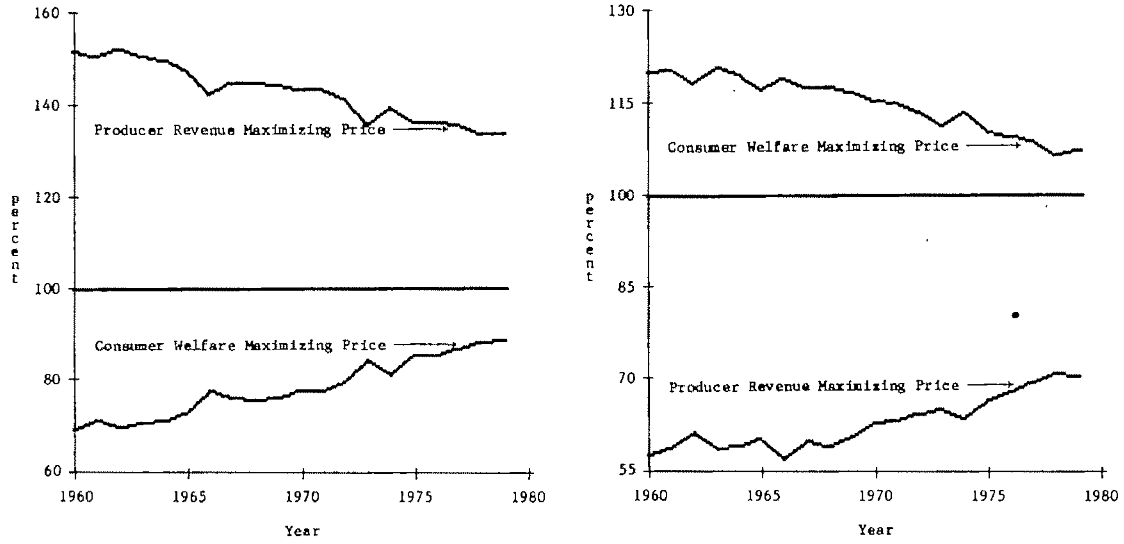
"Optimal" prices as a percentage of actual prices

Figure 1. Weighted average price received by farmers for all milk, 1960–79

For milk used in butter, evaporated milk, and frozen products, the difference in cents/cwt between the actual price and the consumer welfare-maximizing price has widened slightly over the twenty years (table 2). On a percentage basis, however, the actual prices for all use classes except cheese have become steadily closer to the price which would have maximized consumer welfare (figure 2). In all cases except cheese, the actual prices, even in 1960, were closer to the consumer welfare-maximizing prices than to producer revenue-maximizing prices.



Butter **Cheese**



Fluid products **Frozen products**

Figure 2. "Optimal" prices for milk used in various dairy products as a percentage of actual prices, 1960–79

Conclusions

This study has corroborated the results of some previous studies. Given the amount of milk actually marketed, prices of the various use classes of milk are not set to maximize consumer welfare. Hence, producer revenue is somewhat higher than if milk were priced more in line with consumer interests and there occurs a transfer of income from consumers to producers.

On the other hand, prices of the various use classes of milk are also not set to maximize producer revenue. In fact, given the quantity of milk marketed in each of the past twenty years, milk prices have been closer to those that would maximize consumer welfare than to those that would maximize producer revenue. This is even more true today than it was in 1960 and may indicate that the regulatory authorities have, in recent years, recognized (*a*) less need for farm income enhancement, and/or (*b*) the voice of those speaking for consumers. The diminution in producer advantage noted here appears to be an empirical verification of theoretical arguments emanating from Stigler's theory of regulation as reformulated by Peltzman.

One of the frequently argued benefits of existing dairy programs is price and marketing stability (Dobson and Salathe and Hallberg). The relatively small implied consumer-to-producer transfers of the late 1970s resulting from classified pricing may be a small price to pay for the stabilizing aspects of classified pricing. It is less easy to make the same claim for the early 1960s.

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Farm Real Estate Price Components, 1920–78

Emery N. Castle and Irving Hoch

The research reported demonstrates that farm real estate price involves important components in addition to the capitalized value of rent for the services of land and buildings in farm production, develops an expectations model for the farm real estate market, and compares predictions from the expectations model with farm real estate prices for the 1920–78 period. Capitalized rent explains only about half of real estate values both in the 1970s and over the longer 1920–78 period. The remainder can be explained by the capitalization of capital gains, including real gains or losses from price level changes.

Key words: capital gains, capitalization, capitalized value of rent, farm real estate prices, inflation effect

This paper has three objectives: (*a*) to demonstrate that farm real estate price involves important components additional to the capitalized value of rent for the services of land and buildings in farm production; (*b*) to furnish at least the rudiments of a model explaining operator behavior in terms of expectations; and (*c*) to compare the results of the expectations model with actual agricultural real estate price behavior since the early 1920s.

To pursue these objectives, we show that capitalized rent generally explains only a portion of real estate value, amounting to roughly half the total both in the 1970s and over the long period 1920–78. Our expectations model attempts to identify and differentiate monetary components that a prospective investor uses in constructing an expected real estate price; we then estimate annual values for those components and employ their respective totals to predict actual prices. Here, our predictions are not very successful for the depression years, but they show considerable success thereafter. We think this encourages further work along these lines.

Our results add to a considerable literature (Boyne; Crowley; Hathaway; Hopkin, Barry, Baker; Johnson; Melichar; Plaxico and Kletke; Scott).

Basic Thesis

We see the typical prospective investor in farm real estate as forming an expectation of next year's price. Then, if expected price exceeds current price, he will want to buy real estate; if current price exceeds expected price, he will want to sell, or at least not buy, real estate. If all prospective investors behave in this fashion, a market change will be set in motion, and next year's price will move toward the expected price.

The expected price contains two major components, with an important subsidiary component. The first component is the capitalized value of the current year's net contribution of real estate to agricultural income. We call this the earnings component; label it V_1 and measure it by the capitalized value of net rent obtained on owned real estate. Net rent is the pure return on real estate capital. The earnings component is identified in textbooks as the determinant of real estate value.

However, we see additional factors affecting value, all of which are subsumed under a second component, called the real capital gains component and labeled V_2. The value of V_2 is determined by all the forces which cause real estate prices to change relative to the gen-

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eral price level, causing real growth (or decline) in real estate value. In particular, we see a prospective investor operating under the expectation that real change in the per acre value of land and buildings is $\hat{m}_{t+1}P_t$, where t refers to the current year and P_t is this year's price. The term $\hat{m}_{t+1}$ is a fraction expressing expected gain in price next year relative to current price. We now make the specific assumption that $\hat{m}_{t+1}$ equals m_t, where m_t is the fraction expressing real growth in the current year, obtained after accounting for change in the general price level. Finally, we posit that the investor treats this capital gain as income and that he further expects it to occur in perpetuity. He can then capitalize the stream of returns by dividing by the appropriate discount rate. The notion that capital gains are themselves capitalized may appear novel, but we will document its occurrence by applying discounting formulas in the hypothetical situation of constant annual rent increases.

A subcategory of V_2, which we call the price level component and label V_3, is very important. It arises because general price level changes cause changes in the real value of debt. Unless interest rates correctly reflect changes in the price level and financial participants correctly anticipate them, borrowers are better off and lenders are worse off when the price level increases; the opposite occurs when the price level declines. The purchase of real estate usually entails debt acquisition, and the change in the real value of debt can be viewed as a joint product of agricultural output. Debt can be valuable or costly in its own right, depending on the investor's expectation of change in the general price level. If valuable, the purchase of real estate may be a prerequisite for the acquisition of debt, which could be the primary source of gain. Investor expectations about price level changes can be quite complex, but we will make the simplifying assumption that, for V_3, the current rate of price level change, f_t, is expected to continue indefinitely. Then, real gains or losses from debt acquisition will depend on D_t, debt acquired per acre of real estate, and on the difference between f_t and f^*_t, where f^*_t is a response to changes in the price level that is embedded in the interest rate. Again, we specify that annual gains or losses will be capitalized by an appropriate discount rate.

Even though it is the product of price level change, the expected gain or loss expressed by V_3 is stated in real terms. Because V_3 does not necessarily account for all real gains or losses, we treat it as a component of V_2. This is because V_2 accounts for all expected real changes in value. If there is a gain from acquiring real estate debt, knowledgeable investors will bid up the real estate price, increasing V_2.

We use V to designate our total expected real estate value, the sum of V_1 and V_2. It will often be useful to distinguish V_3 explicitly by writing $V = V_1 + V^*_2 + V_3$, where $V^*_2 = V_2 - V_3$, with V^*_2 labeled the net sectoral component—the latter accounting for capital gains factors specific to the agricultural sector. Ruttan argues that no one has successfully separated the impacts on land price of productivity increases, opportunity cost in nonagricultural use, and general inflation (p. 898). Our components furnish a start towards that separation, with V_3 accounting for inflation and V^*_2 for Ruttan's remaining items.

Underlying Economic Relationships

From an accounting point of view, our expectations model generates predicted values as of each year. However, each prediction corresponds to an economic scenario involving a predicted constant annual change in rent. For that scenario, the capitalization of capital gains can be demonstrated. Further, that scenario can be considered in more depth with standard factor market analysis.

Consider a hypothetical situation where rent in the current year is R, having increased by a real amount, C, over the preceding year. Assume that rent next year will be $R + C$, and that it will increase by C every year thereafter, in perpetuity. Hence, the future stream of returns to the landowner will be $(R + C)$, $(R + 2C)$, $(R + 3C)$, $(R + 4C)$, and so on. If this stream is discounted to the present by an appropriate rate, I, the capitalized value is as follows (where the base year is 0):

$$V = \frac{(R + C)}{(1 + I)} + \frac{(R + 2C)}{(1 + I)^2} + \frac{(R + 3C)}{(1 + I)^3} + \frac{(R + 4C)}{(1 + I)^4} + \ldots = \sum_{s=1}^{\infty} \frac{R + sC}{(1 + I)^s}.$$

It can be shown that this expression simplifies to $(R + C)/I + C/I^2$. In obtaining that result, we will make use of the relation

$$\sum_{s=1}^{\infty} \frac{1}{(1+I)^s} = \frac{1}{I},$$

obtained from the standard discounting formula.[1] We can write our capitalized value as

$$V = R \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} + C \sum_{s=1}^{\infty} \frac{s}{(1+I)^s}.$$

Intuitively, we can evaluate the second sum by grouping it as follows:

$$\frac{1}{(1+I)} + \frac{1}{(1+I)^2} + \frac{1}{(1+I)^3} + \ldots$$
$$+ \frac{1}{(1+I)^2} + \frac{1}{(1+I)^3} + \ldots$$
$$+ \frac{1}{(1+I)^3} + \ldots .$$

Algebraically, we can write that grouped sum as

$$\sum_{s=1}^{\infty} \frac{s}{(1+I)^s} = \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} + \frac{1}{(1+I)} \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} + \frac{1}{(1+I)^2} \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} + \ldots .$$

Now apply the standard discounting formula to obtain

$$\left(\frac{1}{I}\right) + \frac{1}{1+I}\left(\frac{1}{I}\right) + \frac{1}{(1+I)^2}\left(\frac{1}{I}\right) + \frac{1}{(1+I)^3}\left(\frac{1}{I}\right) + \ldots .$$

But this simplifies to

$$\left(\frac{1}{I}\right) + \left(\frac{1}{I}\right) \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} = \left(\frac{1}{I}\right) + \left(\frac{1}{I}\right)\left(\frac{1}{I}\right).$$

Collecting terms, we obtain $V = (R + C)/I + C/I^2$, where $(R + C)/I$ corresponds to our V_1 and C/I^2 to our V_2. Note that C/I fits the standard definition of capital gains, so that $\frac{C/I}{I}$ involves the capitalization of capital gains.[2] As a numerical example, consider $R = 10$, $C = 1$, and $I = .1$; then $V = 11/.1 + 1/.01 = 110 + 100 = 210$. Though artificial, the example illustrates the significance of capital gains in capitalization. A prospective perpetual gain in rent that equals 10% of current service flow accounts for roughly half of capitalized value.

The upward shift of rent for farm real estate can emerge from demand or supply shifts, as in figure 1, or from some combination. (Figure 1 shows the first four of a long sequence of years.) The demand for real estate services equals value of marginal product (VMP), which will shift up because of an increase either in farm product prices or in the productivity of farm real estate, as exhibited in the right-hand panel of figure 1.

Supply shifts toward the origin also will increase rents over time, as shown in the left-hand panel of figure 1. A major reason for such shifts is increased opportunity costs. Increases in nonagricultural demand for land, particularly for urban use, will drive land out of farming as long as its VMP is unchanged. For simplicity, we abstract from the building component of real estate and present supply as perfectly inelastic; however, our basic conclusions are unaffected if land supply has some but not perfect elasticity. The USDA estimates that during the past decade 28.7 million acres of agricultural land have been diverted to urban uses, including residences and highways (Dideriksen, U.S. Department of Agriculture 1977). While this amounts to only 3% over the period 1968–77, or 0.3% per year, the prospect of conversion should influence the price of more acres than are, in fact, converted in any period of time. A small price increase in a given year can have a magnified effect if recurrence is expected over many years.

Figure 1 also shows that current rent need not reflect future changes in market conditions. Current rent is obtained as the intersection of S and VMP, since a producer will not pay more than the current value of marginal product for the use of the land. A prospective purchaser, however, should be willing to pay approximately the full capital value, knowing that he will receive an increasing stream of

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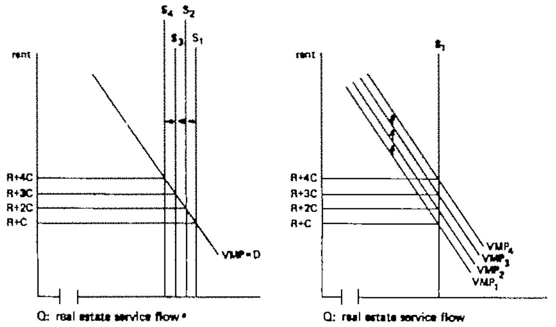
[1] The authors are indebted to Mark Sharefkin of Resources for the Future for this alternative proof: Since

$$\frac{d}{dI} \frac{1}{(1+I)^s} = -s\left[\frac{1}{(1+I)^{s+1}}\right],$$

It follows that

$$\sum_{s=1}^{\infty} \frac{s}{(1+I)^s} = -(1+I)\frac{d}{dI} \sum_{s=1}^{\infty} \frac{1}{(1+I)^s} = -(1+I)\frac{d}{dI}\left(\frac{1}{I}\right) = \frac{1+I}{I^2}.$$

[2] This confirms Crowley's intuitive doubts of the classic argument that it is a mistake to treat capital gains as income (p. 52).



[a] A break appears in the Q axis to convey the notion that the shifts occur over a very long time.

Figure 1. Sources of increasing rent for services of farm real estate

rents if the land is retained in agriculture or a corresponding capital amount if he sells.

Though we have drawn figure 1 to exhibit expected increases in rent and consequent capital gains, our general formulation also encompasses expected decreases in rent and consequent capital losses. Further, our model not only encompasses current and expected future productivity of real estate services in agriculture but also accounts for sources of capital value that bear no particular relation to agricultural productivity. They are a joint product with farm output. In addition to real gains from inflationary erosion or real losses from deflationary magnification of debt (V_3), numerous other items can be identified, including expected gains or losses from changes in the rate of inflation (or deflation), government programs that help or harm owners of real estate without affecting productivity, and the tax advantages of financial gains received as capital rather than income. Returns in the form of capital gains can yield real benefits because taxes are paid on those gains only if the property is sold. Then they involve lower tax rates on income. As Plaxico and Kletke suggest, "unrealized" capital gains can be viewed as a tax-deferred income stream (1979, p. 327). The capitalized benefits of all of these items are included in our V_2.

Making the Model Operational

In this and succeeding sections, we employ the variables appearing in table 1, which is presented here for convenience. To apply our model, we make it operational by answering some technical questions. Several concern the appropriate interest rate. Here, our answers depend on how we assume inflation (or deflation) affects a particular stream of returns.

If an annual flow of funds does not inflate (or deflate) with the general price level, then the market interest rate, I_t, is the proper discount rate to use in capitalization. (This assumes the market interest rate is in equilibrium.) On the other hand, if the annual return does change with the price level, then the proper interest rate is an invariant "real" rate, which we label i and somewhat arbitrarily set at .05. We interpret i as the real internal rate of return or time preference.[3]

The actual market interest rate on farm real estate loans varied between .04 and .0608 over the period 1920–66 (USDA 1941, 1972, Jul. 1978b). Hence, the .05 assumption seems reasonable.

Next, we assume that the market interest rate in period t can be written $I_t = i + f^*_t + if^*_t$, where f^*_t accounts for any incorporation of the change in the general price level, f_t, into the interest rate. If f^*_t fully accounts for f_t, then f^*_t equals f_t. However, an inspection of interest rates suggests that in periods of inflation, f^*_t lags behind f_t, while in periods of deflation, f^*_t has a minimum value of $-.01$. Thus, I_t is inflexible downward. The appropriate factor to apply in discounting is $(1 + i)(1 + f_t)$ since $\frac{1}{(1 + i)(1 + f_t)}$ is the present real value of a dollar to be received a year from now. Consequently, the "proper" market interest rate can be defined as $(1 + i)(1 + f_t) - 1 = i + f_t + if_t$, which we label J_t. Thus, if the market interest rate is .10, with i equal to .05, then f^*_t must be .0476. This follows from the relation $.10 = .05 + .0476 + (.05)(.0476)$. If the rate of inflation is above .0476, then f^*_t has lagged behind f_t. Note that $I_t = J_t$ if $f^*_t = f_t$, so J_t can be interpreted as the equilibrium value for I_t. In short, a stream of fixed money values should be discounted by J, rather than I. In practice, however, discounting by I should introduce only modest error.

Discounting a fixed money stream of returns by the proper market rate of interest (I or J) is equivalent to discounting a corresponding net stream of variable money returns by i. This net stream would be obtained as a residual after an inflation (or deflation) component is sub-

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[3] This is not necessarily the ideal rate of discount for a particular individual, which should be the highest of the following: real internal rate of return; highest real rate of return from nonfarm investment; and real rate at which the farm entrepreneur will save from farm income.

Table 1. Symbols and Definitions for Major Variables

Symbol	Definition
B_1	Building costs on rented farm real estate, per acre.
B_2	Building costs on owned farm real estate, per acre.
D	Debt on farm real estate, per acre.
f	Inflation rate (change in Consumer Price Index, expressed as a fraction).
f^*	Price level component embedded in interest rate, measured as $(I - .05)/1.05$.
I	Market interest rate (treated as equal to rate for new farm mortgage loans).
i	Real internal rate of return or time preference, set at .05.
J	Interest rate fully accounting for inflation or deflation: $J = (1 + i)(1 + f) - 1$.
m	Real growth rate in price of farm real estate: $(P_t/P_{t-1}) - 1 - f_t$.
P	Price of farm real estate, per acre.
R_1	Gross rent on rented farm real estate, per acre.
R_2	Gross rent on owned farm real estate, per acre.
R^*	Net rent on owned farm real estate, per acre, defined as $R_2 - T_2 - B_2 +$ adjustment to account for sinking-fund depreciation, rather than straight-line depreciation.
t	Time subscript referring to current year; $t - 1$ refers to previous year, $t + 1$ to following year.
T	Last year in a time sequence for a stream of returns.
T_1	Taxes on rented farm real estate, per acre.
T_2	Taxes on owned farm real estate, per acre.
V	Expected price of farm real estate per acre. V_t is formed in year t and used to predict P_{t+1}. $V = V_1 + V_2$.
V_1	The earnings component of V; measured as the capitalized value of net rent on owned real estate per acre: $R^*_t/i = R^*_t/.05$.
V_2	The real capital gains component of V, measured as capitalized value of capital gain, per acre: m_tP_t/I_t.
V^*_2	$V_2 - V_3$; the net sectoral component, basically accounting for factors specific to the agricultural sector.
V_3	The price level component of V; measured as gains or losses from changes in the real value of debt, per acre: $D_t(f_t - f^*_t)/I_t$.

tracted from the given fixed return and added to capital. Thus, the real value of capital is unchanged with price level change. If an investor does not follow this procedure in practice, then he is consuming capital as well as interest.

For V_1, we are concerned with discounting net rent, R^*_t. Net rent is defined as the service flow of real estate inputs net of taxes, depreciation, and operating costs. Because our expectations model uses V_2 to account for real changes relative to general price level changes, it is proper to impose the expectation that farm product and factor prices, including R^*_t, change with the general price level. A rent of R^*_t this year will become $(1 + f_t)R^*_t$ next year. Hence, the stream of future rents can be discounted to the present by writing:

$$\frac{R^*_t(1 + f_t)}{(1 + i)(1 + f_t)} + \frac{R^*_t(1 + f_t)^2}{[(1 + i)(1 + f_t)]^2} + \ldots + \frac{R^*_t(1 + f_t)^T}{[(1 + i)(1 + f_t)]^T},$$

which simplifies to R^*_t/i as T goes to infinity.

A fairly straightforward equation for V_3 can also be developed, using the discount rate for fixed annual money returns.

If a lender accepts the market rate of interest, I_t, in negotiating his loans, then a stream of \$1.00 payments for T years is treated as the equivalent of a loan of S^*_t by the lender, where $S^*_t = \left[1 - \frac{1}{(1 + I_t)^T}\right]/I_t$. Say a borrower obtains a loan of S^*_t by promising to pay the \$1.00 per year for T years, but the borrower discounts that stream to the present by applying the proper interest rate, J_t, to obtain S_t, where $S_t = \left[1 - \frac{1}{(1 + J_t)^T}\right]/J_t$. Both S^*_t and S_t are obtained by applying the standard discounting formula. Then the borrower has gained $S^*_t - S_t$, which is the amount borrowed minus his perceived actual value of the repayment on that amount. Per dollar borrowed, the gain is $(S^*_t - S_t)/S^*_t$. Hence, if D_t can be borrowed per acre of real estate in year t, the gain per acre is $D_t(S^*_t - S_t)/S^*_t$, in year t prices. We define this gain as V_3.

If the borrower further assumes that he can refinance the loan in perpetuity at the initial terms, then T becomes infinite in the original expressions for S^*_t and S_t. When those expressions are entered in the equation defining V_3, we obtain

$$V_3 = D_t\left[\left(\frac{1}{I_t} - \frac{1}{J_t}\right)\Big/\frac{1}{I_t}\right] = D_t\left(\frac{J_t - I_t}{J_t}\right) = D_t\left[\frac{(f_t - f^*_t)(1 + i)}{J_t}\right].$$

(Note that if $I_t = .10$ and $J_t = .12$, then $V_3 = .167\,D_t$, which seems substantial.) The V_3 formula is close to the result an investor would obtain by using the intuitive approach of treating $D_t(f_t - f^*_t)$ as his annual gain and then capitalizing by dividing by I_t. Denote the former result as $V_{3(J)}$ and the latter as $V_{3(I)}$. The behavior of these rival estimates yields the following conclusions. By definition, both estimates become zero if $f_t = f^*_t$. In practice, $V_{3(J)}$ is approximately 10% less than $V_{3(I)}$ during inflationary periods. Thus, in our example of $I_t = .10$ and $J_t = .12$, the corresponding inflation factors are $f^*_t = .0476$ and $f_t = .0666$. Hence, $V_{3(I)} = (.0190/.1)D_t = .190\ D_t$. The difference between $V_{3(J)}$ and $V_{3(I)}$ is 12%. In deflationary periods, f_t is negative. If f_t is less than $-.05$, i.e., less than $-i$, then the original sum for $V_{3(J)}$ goes to minus infinity. Then our summation formula becomes inapplicable. There are various ways around this difficulty, but all involve more complication than necessary at this stage of analysis. Instead, in the empirical application of our model, we capitalize by I_t rather than J_t, with only slight inaccuracy in inflationary periods, and with estimated finite financial losses in deflationary periods. It is true that during deflationary periods for high enough absolute values of $f_t (f_t < -.025)$, both $V_{3(I)}$ and $V_{3(J)}$ imply losses greater than owners' equity. In that event, the rational owner would let his property be foreclosed. The loss of equity $(P_t - D_t)$ would be the maximum loss sustained. Such a "stop-loss" rule was applied in our empirical work.

Turning to V_2, recall that the real change in the per acre value of land and buildings in year $t + 1$ was assumed to be m_tP_t, where m_t is a fraction measuring real growth in the current year relative to the previous year. We now make that assumption more explicit by writing

$$P_t = (1 + f_t)P_{t-1} + m_tP_{t-1},$$

with m_t defined by this relation. Our prospective investor assumes that m_t is invariant over future years. He further expects to receive a perpetual stream of returns of m_tP_t per year. We have not specified whether those returns are obtained in current or constant dollars. Different investors may well have different expectations. If they are obtained in current dollars each year (or in fixed money amounts), then the present value of the stream of returns is obtained by capitalizing by the equilibrium interest rate, J_t, paralleling V_3. On the other hand, if the returns are obtained in constant dollars (or in fixed real amounts), then capitalization occurs by dividing by i (or .05), paralleling V_1. Since V_3 is a major component of V_2, we can argue that at least a large part of V_2 should involve capitalization by J. In practice, we made the simplifying assumptions that all of the returns underlying V_2 ought to be capitalized by J, but that we could replace J by I without much accuracy loss. The errors introduced by these assumptions are partly offsetting.[4] However, in a marked inflation, the first error will probably be larger, understating V_2.

Measurement of Variables

We now briefly describe data sources and measurement procedures.[5]

Direct measures of I_t, P_t, D_t, f_t, and m_t were obtained from available published series; I_t was obtained from U.S. Department of Agriculture (USDA 1941, p. 597; 1972, p. 597; and from ESCS CD83, p. 22); P_t was obtained from USDA (ERS 520, p. 2, and from ESCS CD83, p. 22); D_t was obtained using scale factors from Board of Governors of the Federal Reserve System (p. 72), applied to P_t. The BLS Consumer Price Index was employed for f_t, and m_t was derived from f_t and the P_t series. Our data spanned the period 1920–78. Since we made one-year predictions with V_t predicting P_{t+1}, the index t ran from 1920 to 1977, and $t + 1$ ran from 1921 to 1978.

The real estate variables consisted of U.S. average values per acre. We developed an estimate of R^*_t, net rent per owned acre, from published series on the rental value of rented farm real estate and building costs and taxes on owned real estate (see table 1 for the definition of net rent). Rental payments were obtained from ESCS (Statist. Bull 6–9, p. 44; these were converted to per acre values using data on total acreage from U.S. Bureau of the Census, pp. 1–6; ERS 520, p. 2; and ESCS CD83, p. 4). Farm real estate taxes per acre were obtained from USDA (1953, p. 625; 1971, p. 498; 1977; and 1978, p. 472). Total and per acre farm building costs, including repairs, operation, and straight-line depreciation were obtained from total farm acreage and ESCS (Statist. Bull. 609, pp. 46, 48).

Since it is plausible that building input on rented real estate is less than on owned real estate, we somewhat arbitrarily accounted for this differential by multiplying rented real estate by 4/3 to compute an estimated rent on owned real estate. This assumes that building input on rented real estate was 0.40 of that on owned real estate. This 4/3 scale factor is consistent with two side conditions: (*a*) a rate of return on building investment equal to the rate of return on land investment, and (*b*) the distribution of real estate value of .75 to land and .25 to buildings, based on U.S. data in Hoch.

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[4] If we capitalize by J when, in fact, we should use i, we understate V_2 because J is greater than i; but if we capitalize by I when we should use J, we overstate V_2 because I is less than J.

[5] Additional detail on measurement and results can be obtained from the authors.

We next subtracted taxes, building operating costs, and building depreciation from rent to calculate a net rental figure. Building depreciation in the published series was on a straight-line basis. It was converted to a proper sinking fund measure and subtracted from gross rent (along with taxes and building operating costs). This makes buildings, as well as land, an infinite life asset. Net rent can then be viewed as the perpetual annual return to real estate (in farm production) which a purchaser would obtain. Capitalization by division by .05 yields V_1.

Both adjustments to published series (scaling by 4/3, and using sinking fund depreciation) tend to increase net rent, and hence, the earnings component contribution to total real estate value.

Empirical Estimates and Predictions

We tested our model by comparing expected prices derived from its application to actual real estate prices.

Summarizing earlier results, our empirical estimates were computed from the following:

$$V_{1t} = R^*_t/.05,$$
$$V_{2t} = m_t P_t / I_t,$$
$$V_{3t} = D_t(f_t - f^*_t)/I_t,$$

where $f^*_t = (I_t - .05)/1.05$, and

$$V^*_{2t} = V_{2t} - V_{3t}.$$

The capitalization factor, I, is a key parameter. It was treated as equivalent to the market rate of interest (the rate on farm mortgage loans) despite some controvery on this approach.[6]

We interpreted $V_{1t} + V_{2t} = V_t$ both as the expected price of our typical investor and as a prediction of market price. We established this correspondence to test our estimates as predictions against actual values. However, there are some differences between the two which we discuss below. Finally, all components of V_t, and V_t itself, were multiplied by $(1 + f_t)$ because we were predicting P_{t+1} on the basis of estimates for year t. Since the inflation (or deflation) rate, f_t, was assumed to hold indefinitely, we converted year t expected values to year $t + 1$ predictions by inflating (or deflating) them with f_t.

All of our estimates involved deflation to real terms. We first obtained an initial series of predictions in which V_t and its components were in current dollars. Then, a further scaling was carried out to convert all results to constant dollars, using 1967 as the base year. Deflation was carried out in both steps. To clarify the point, consider a 1977 example. The 1977 annual rate of inflation was .065. If one were to receive \$1.25 in 1980, it would be worth \$1.25/(1.065)^3, or \$1.035 at the 1977 price level. The latter, deflated figure corresponds to our current dollar series as of 1977. However, the 1977 Consumer Price Index was 181.5 on a 1967 base, so we converted to 1967 dollars by dividing \$1.035 by 1.815, which is \$0.570. This corresponds to our constant dollars series.

For selected years, table 2 presents annual V_t values and their underlying components treated as predictions. Table 2 also shows corresponding actual prices in constant dollars and ratios of expected price (V_t) to actual price.

Deflated actual prices continously declined from 1921 (the initial year in table 2) until after the start of World War II, reaching a minimum in 1942. Thereafter, a gradual increase occurred through 1968, followed by a slight dip until 1972. Then a marked acceleration occurred in subsequent years.

Our predictions for individual years were typically very different from the actual values for those years (table 2). This is partly because our model is still in an early stage of development. To some extent, this also might reflect the basic difference between expectation and prediction, with expectation not necessarily an exact prediction. Instead, V_t can be interpreted as a signal to buy or sell, with the market only tending to move in the directions indicated. Even an improved model might yield expected prices displaying wider swings than actual market changes. A particular ex-

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[6] We measured market interest rates using rates on new farm mortgage loans by life insurance companies and the Federal Land Bank. For a discussion of alternative sources of farm mortgage credit, see Hopkin, Barry, and Baker. Some argue that the appropriate capitalization rate is the rate of return available on other assets in the same risk class (Adams, Plaxico and Kletke, and Dunford). We use the market interest rate both because of estimation ease and because we doubt that farmers can easily transfer capital from farmland to other investments of comparable risk. A unique feature of real property investment is the extent to which it permits debt to be acquired.

Table 2. Estimated Returns from Research from Different Types of Technical Change in the

Forecast year, $t + 1$	V_{1t}	V_{2t}	V_{3t}	V_t	P_{t+1}	$\frac{V_{1t}}{P_{t+1}}$	$\frac{V_t}{P_{t+1}}$
1921	35.39	−161.63	248.36	122.12	121.27	0.292	1.007
1926	25.14	−71.40	23.58	−22.68	98.11	0.256	−0.231
1931	2.70	81.03	−34.50	49.23	96.49	0.028	0.510
1936	12.43	−21.64	34.44	25.24	77.11	0.161	0.327
1941	18.16	−41.93	23.61	−0.16	72.56	0.250	−0.002
1946	80.29	105.74	38.09	224.12	90.60	0.886	2.474
1951	64.85	−73.82	22.12	13.14	96.40	0.673	0.136
1956	39.27	96.51	5.75	141.53	111.79	0.351	1.266
1961	31.73	54.70	8.04	94.47	131.70	0.241	0.717
1966	70.28	90.04	19.07	179.40	162.55	0.432	1.104
1970	52.52	−54.26	45.46	43.72	167.67	0.313	0.261
1971	52.60	−70.90	29.19	10.89	167.35	0.314	0.065
1972	50.86	−14.13	10.27	47.00	174.78	0.291	0.269
1973	106.83	91.85	2.23	200.91	184.82	0.578	1.087
1974	196.91	79.12	51.04	327.06	204.47	0.963	1.600
1975	158.58	148.05	118.09	424.73	212.78	0.745	1.996
1976	120.56	30.14	65.84	216.54	226.98	0.531	0.954
1977	85.57	140.16	17.44	243.16	247.93	0.345	0.981
1978	67.96	209.46	47.61	325.03	250.77	0.271	1.296

ample of this difference occurs in considering maximum losses and minimum prices. An investor would view his maximum possible loss as equal to his equity, or $D_t - P_t$. From the market point of view, however, the minimum price can be only zero and not a negative number. Rather than pay someone to accept a real estate transfer, property can be abandoned.

Our V_t performs much more adequately in prediction when averages over time are considered. Table 3 presents averages over decades and over all years. Table 4 presents ratios based on those averages, including both the ratio of V_{1t} to P_{t+1} and of V_t to P_{t+1}. Table 3 includes averages for both current and constant dollar series while tables 3 and 4 both present the plausible variant in which all negative values of V_t were set at zero.

Over all years, the current dollar average for predicted price per acre, V_t, is close to that for the actual price ($102.69 being 92% of

Table 3. Average Values of Predicted Price Components, Predicted Price and Actual Price, By Time Period

Period	V_{1t}	V^*_{2t}	V_{3t}	V_t	V_t, with minus values set at 0	P_{t+1}
			($, current [undeflated])			
Decade						
1920s	11.25	−18.10	3.34	−3.51	13.35	54.00
1930s	1.14	−3.05	−5.78	−7.69	6.30	35.30
1940s	40.99	−31.77	50.33	59.55	62.93	46.90
1950s	42.86	34.05	28.20	105.11	105.11	87.40
1960s	51.39	73.85	16.17	141.42	141.42	146.50
1970s	152.33	114.00	67.42	333.75	333.75	315.00
All Years	48.90	27.48	26.31	102.69	108.30	111.76
			($, constant [deflated], 1967 = 100)			
Decade						
1920s	21.56	−33.37	4.83	−6.97	25.65	104.23
1930s	1.97	−8.29	−14.60	−20.92	14.25	82.64
1940s	68.20	−50.28	81.20	99.11	106.27	82.21
1950s	53.38	42.00	34.42	129.80	129.80	107.41
1960s	53.02	78.10	16.05	147.17	147.17	151.77
1970s	99.15	62.17	43.02	204.34	204.34	204.17
All Years	49.17	15.08	27.61	91.86	104.22	120.96

Table 4. Ratios of Average Values of Capitalized Rent and Predicted Prices to Average Values of Actual Prices, by Time Period, in Deflated Dollars (1967 = 100)

Period	Capitalized rent measure: V_{1t}/P_{t+1}	Predicted Price Measure: V_t/P_{t+1} Initial Measure	Predicted Price Measure: V_t/P_{t+1} With minus values set at 0
Decade			
1920s	.207	−.067	0.246
1930s	.024	−.253	0.172
1940s	.830	1.206	1.293
1950s	.497	1.208	1.208
1960s	.349	0.970	0.970
1970s	.486	1.001	1.001
All Years	.406	0.759	0.867

$111.76). When negatives are set at zero, the two become even closer ($108.30 being 97% of the P_{t+1} average). However, the deflated dollar comparisons are not so close, with predicted price equal to 76% of actual for the original V_t, and 87% when minus values are set at zero. But it is clear from table 4 that the understatement reflects the very low predicted values of the 1920s and 1930s, which included many negatives. Though exaggerated, those predictions contain good advice. If a prospective investor took them seriously throughout the 1920s and 1930s, he would have purchased farm real estate only in 1921, not returning to the market until 1944. The decade averages for V_t in the 1940s and 1950s were roughly 20% above the corresponding averages of actual prices. The 1960s and 1970s averages closely approximated the corresponding actual price values. As predictions, the V_t averages performed well over the last two decades. This suggests that real estate was undervalued during the 1940s and 1950s, slightly overpriced during the 1960s, and properly valued (to a precise degree) during the 1970s.

For the original readings, with negative V not set at zero, the components of V as percentages of V had the following average values:

	V_1	V^*_2	V_3	V
	(Percentage of Total)			
All Years				
Current dollars	47.6	26.8	25.6	100.0
Constant dollars	53.5	16.4	30.1	100.0
1970–78				
Current dollars	45.6	34.2	20.2	100.0
Constant dollars	48.5	30.4	21.1	100.0

Differences between the current and constant dollar data reflect different weights attached to individual years. Current dollar measurement gives greater weight to years of inflated dollars.

In all cases, the earnings component, V_1, accounts for about half the total predicted value, with V^*_2 and V_3 each accounting for a substantial (but variable) part of the remainder. Over all years, V_3 had a somewhat larger share than in the 1970s. This is somewhat surprising, given the 1970s inflation, but explainable by the relatively large values for V_3 in the 1940s and the negative values for V^*_2 throughout the 1940s.[7]

We argued that capitalized rent falls considerably short of explaining farm real estate values. This proposition receives strong support from the ratio of V_{1t} to P_{t+1} in tables 2 and 4. For all years, the average value of the ratio was only 40%. Though some of this may be caused by the low rents of the 1920s and 1930s, all other decade averages for this ratio were below 1.0; 1943–49 was the only extended period when the ratio was near or above 1.0. In the 1960s, the ratio was around .35, and in both the 1950s and 1970s, the ratio was about .5. Hence, it is obvious that other forces are at work, and V^*_2 and V_3 are first approximations of those forces.

Agricultural real estate has been a highly attractive farm operator investment in recent years, with much of the attraction presumably related to the high and increasing levels of V^*_2 and V_3.[8] In contrast, the pattern for V_1 in table 2 suggests that the real cost of real estate as an input has shown little trend over the past two decades for the farmer who has also been a landowner with an average amount of real estate debt. The attractiveness of real estate as an investment may have reduced incentives for adopting land-saving practices and technologies. This helps explain larger machinery (allowing more land to be utilized per worker), larger acreage per farm, increased acreage farmed by owners and part owners, a decline in the acreage farmed by full tenants, and a much lower increase in land productivity than in labor productivity during the 1970s.

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[7] Melichar interprets capital gains in agriculture as reflecting growth in current returns to production assets. This interpretation may correspond to an upward shift in productivity, which we see as one part of V_2. However, it appears to neglect other sources of gain, particularly those embedded in V_3.

[8] The relatively high proportion of value attributable to V^*_2 and V_3 seems consistent with estimates of marked increases in the real value of land and buildings. Boyne estimates 1940–60 farm capital gains as $29.4 billion, with $25.6 billion attributable to real estate. Evans presents ESCS estimates of 1960–78 farm capital gains of $573.0 billion, with $428.0 billion attributed to real estate (p. 13, 16).

Conclusions

In extending our model, a variety of refinements and alternative formulations might be examined. We could make *i* variable, given evidence on shifts in time preference over time; and there could be attempts to account for variations in expectations between different groups of investors. Because V_2 is a composite, its further disaggregation would be an improvement. More complicated discounting techniques could be used, or we could assume that *T* was finite, or that *m* and *f* were variable.[9] Certainly, our poor predictions for the decades of the 1920s and 1930s suggest that investors expected that deflation would not continue indefinitely. In fact, we experimented with varying predicted *f* for a *T* of 25 years, with an f_t of .065 and an I_t of .0935, their 1977 values. If f_t is treated as unchanged, then V_3 is positive, and annual gains of $0.169 are obtained per dollar of debt incurred. But an investor predicting that inflation would fall to .041 would calculate that V_3 was zero; if he predicted that inflation would fall to zero, then V_3 would be negative, with annual gains per dollar of debt at -0.474. A corollary is that debtors can suffer considerable losses if inflation is brought fully under control, which suggests political unpalatability in doing so. Finally, we have worked with national data, and it is plausible that microdata covering a specific locale would be an improvement.

Nevertheless, we believe our results are promising and support the following conclusions:

(*a*) Recent increases in agricultural real estate prices cannot be explained on the basis of earnings in agricultural production alone. The capital value of farm real estate appears to involve considerably more than the capitalized value of current rents for its services in agricultural production. It appears to include the capitalized value of a stream of expected future increases (or decreases) in rent plus capital gains (or losses) not associated with service flows in agricultural production.

(*b*) The exact connection between current rents and capitalized value can be severed. Current rents must reflect current value of marginal product, while capitalized value can pick up other sources of gain. Nevertheless, our work supports the conventional view of the capitalization process by extending and clarifying it.

(*c*) Our approach measures the direct contribution of price level changes to real estate values. Those changes appear to have had significant impact since the 1920s (column 3 in tables 2 and 3).

(*d*) Real estate has been an attractive farm operator investment, perhaps more because of changes in V^*_2 and V_3 than V_1. This probably reduced the incentive to economize in the use of land (columns 2 and 3 in tables 2 and 3).

(*e*) Much remains to be explained about real estate price changes relative to other goods and services. Hypotheses include changes in product prices and factor productivity, opportunity cost changes in nonagricultural land use, and gains from changes in financial variables. All merit careful study.

(*f*) The model presented is a promising tool for investigating real estate prices in specific geographic areas as well as real property prices in urban areas.

(*g*) It is incautious, if not foolhardy, to predict the long-run values of the *V* components, although some might expect that V^*_2 and V_3 ought to tend toward zero except in local areas experiencing urban expansion. However, our model does permit us to sort out these components and keep track of them over time.

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[9] Our estimate of V_3 may understate the price level component by not fully accounting for the aggregate effect on land prices of inflationary psychology; that effect could be handled by increases in predicted *f*, and corresponding changes in *m*.

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Some Emerging Rights in Agricultural Land

John B. Braden

Agricultural land use rights have become increasingly complex following new policies for soil conservation, nonpoint pollution control, wetlands protection, and farmland preservation. When viewed in a framework that distinguishes between ownership and exchange of rights, little change is evident in ownership of rights. The added complexity has come mainly in the rules governing exchanges. Farmers are confronted increasingly with rules which allow specific rights to be limited by government with compensation. These rules retain the flexibility of individual ownership while reflecting a growing awareness that the general welfare depends on wise use of agricultural land.

Key words: land use, pollution, property rights, soil conservation, wetlands.

Soil depletion and erosion, agricultural impacts on environment quality, and conversion of farmland to nonagricultural uses are problems which have been with us for a long time. The urgency now attached to protecting water, land, and soil in the United States reflects a growing concern that existing rural land institutions, most of which are not far divorced from the concept of fee simple absolute ownership, may be inadequate (Fischer et al.). Several new devices have been tried or proposed. The purpose of this paper is to set forth a framework within which present reform efforts may be understood and from which flow implications for changes which are appropriate according to legal and economic criteria.

New Initiatives Affecting Rights in Agricultural Land

As long as an abundance of unsettled useful land remained in the United States, separating conflicting activities was relatively easy and cheap. Fee simple absolute ownership of land suited such a context well (Carmichael). As the population grew and the western frontier shrank, however, resolving conflicts increasingly meant limiting the rights of landholders. In the 1920s, zoning was approved by courts as a method of land use control. Since then, building codes, subdivision regulations, open-space controls, and expanded uses of eminent domain have been added as "official" tools for controlling land use (Nicholas Williams). "Unofficial" controls are exercised through property taxes, public works policies, various subsidies, and income tax policies which encourage specific land uses.

Until recently, rural lands had been touched very little by these tools, except for property taxes, condemnations for roads, and agricultural subsidies. However, developments in four areas illustrate recent changes affecting rural lands—soil conservation, nonpoint pollution, protection of wetlands, and farmland preservation.

Soil Conservation

Existing federal soil conservation programs largely reflect initiatives of the 1930s (Held and Clawson, Morgan, Parks). These programs, administered by the Soil Conservation Service (SCS) and the Agricultural Stabilization and Conservation Service (ASCS), rely on the voluntary cooperation of rural landowners and users. Federal technical and financial subsidies for conservation efforts are directed

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by local soil conservation districts and agricultural stabilization and conservation committees, respectively.

Land use regulation was viewed by the U.S. Department of Agriculture (USDA) as an important ingredient of conservation programs from their inception. The SCS was authorized to make its delivery of services subject to compliance with state or local land use regulations. The model state soil conservation district law issued by the USDA in 1936 included provisions for districts to administer land use regulations for controlling soil erosion. However, most states either do not extend this authority to districts or compel such regulations to pass stiff referenda (Craig Williams, p. 379).[1] Where the authority has been available, few districts have employed it. Instead, the voluntary cooperation of land users or owners in USDA conservation programs is relied upon.

In theory, the decentralized administration of federal soil conservation programs should help enlist participants and tailor federal assistance to local conservation needs. Nevertheless, several recent studies (Comptroller General 1972, 1973, 1977; Craig Williams) were highly critical of existing soil conservation programs. In a survey conducted for the Comptroller General's 1977 report, land which had been handled by districts and the SCS was found to be no less subject to erosion than other land. The ASCS and its committee system were criticized for allocating most cost-sharing assistance to projects which accomplish more for farm production and income than soil conservation. A lack of coordination and cooperation between the SCS and the ASCS also was noted.

Whether through administrative shortcomings, inadequate budgets (Benbrook, Craig Williams), or uncooperative landowners, soil losses continued to exceed "tolerance levels" (Wischmeier and Smith) on about 50% of U.S. farmland by 1977 (USDA 1978). The president and Congress responded by passing the Soil and Water Resource Conservation Act of 1977 (RCA; P.L. 95-192). In it the USDA was instructed to appraise soil and water resources on nonfederal lands and to propose policies to further conserve and enhance these resources.[2] Three types of soil conservation policies were considered for the RCA: (*a*) upgrading current voluntary programs; (*b*) purchasing conservation performance; and (*c*) requiring practices or performance to assure conservation. The latter two options imply the identification of new property rights in agricultural land—rights to lose soil and to exchange (sell) those rights. Problems of definition, allocation, and enforcement immediately arise with the identification of such rights. Iowa has made it "the duty" of its property owners to conserve soil (Iowa Code). Soil and water conservation districts in Iowa may establish regulations to require erosion control. However, the state must provide financial assistance to persons forced by such regulations to control erosion. Movement toward defining rights to lose soil is already underway.

Water Quality

As awareness of nonpoint agricultural pollution grew in recent years, the USDA broadened its conservation programs to encompass pollution control measures (Craig Williams). In 1970, pollution abatement was added as a target of ASCS cost sharing. In 1971, the Agricultural Conservation Program of the ASCS was renamed the Rural Environmental Assistance Program to signal a major change in program emphasis. The original name was restored in 1974. However, the major initiatives to address nonpoint pollution have followed from Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). They have been directed by the Environmental Protection Agency (EPA). Since 1978, states have been under EPA notice to implement nonpoint pollution controls. By the summer of 1980, forty-seven states had formulated programs which met EPA approval.

Most state programs rely on voluntary approaches to nonpoint pollution abatement. However, twelve states have taken initial steps toward regulation of agricultural nonpoint polluters (EPA, p.2). In most of these states, owners and users of agricultural land must formulate and follow soil erosion and sediment control plans. Soil and water conservation districts, the SCS, and the extension service provide technical and educational support. Cost-sharing funds for implementing the plans (which specify appropriate "best management practices" for controlling pollutants) are available from the Agricultural Stabilization and Conservation Service and from ten state governments (EPA, chart 1).

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[1] All states now allow rural zoning (Bock). Most rural land regulations are administered by county governments. In the 1930s ordinances were passed in some counties to authorize officials to undertake wind erosion control measures and add the cost to the landowner's tax bill. More recent examples of local land-use ordinances are described briefly by the USDA (1980a, chap. 10).

[2] In August 1981, too late for inclusion here, the USDA completed its final report pursuant to the RCA. See USDA (1980b) for a draft of the summary report. Meanwhile, in the 1980 USDA appropriations bill (P.L. 96-108), Congress instructed the ASCS to confine its conservation cost-sharing activities to measures making significant and enduring reductions in erosion or pollution.

Enforcing water quality regulations is especially difficult for nonpoint pollution because extensive monitoring is required and complicated linkages between water quality and land use practices must be established (Walter, Steenhuis, Haith). Rather than conduct costly programs of routine assessments, most states which regulate agricultural nonpoint pollution enforce those regulations in response to complaints or to obvious and critical problems. Furthermore, many states focus their Section 208 programs on sediment control because, compared to agricultural chemical pollutants, more is known about the effects of land management practices on soil losses. The universal soil-loss equation (Wischmeier and Smith, Wischmeier) provides clearly defined, scientific principles upon which to base program priorities and enforcement actions. Pennsylvania and Iowa, for example, require that erosion be limited to soil tolerance levels rather than basing their regulations on the water quality impacts of soil losses.

The implications for agricultural land use rights are clear. Rights to use land are being conditioned on effects that uses have on others, principally users of water and aquatic environments. For example, the right to grow soybeans on the back forty is increasingly defined as the right to grow soybeans and lose 12 tons of soil per acre and, in turn, drive up the turbidity of the nearby creek. Such refinement in the definition of land-use rights improves the social efficiency with which land is employed. As our insight into physical nonpoint pollution linkages grows, we will become increasingly able to attach the relevant prices (or penalties) to these rights and, consequently, promote their efficient use.

Wetlands Protection

Another section of the 1972 amendments has become the foundation of federal programs to protect wetlands.[3] Section 404 was amended in the 1977 Clean Water Act (P.L. 95-217) to assert federal authority over actions posing significant threats to virtually any wetland. In fact, even routine impacts such as temporary increases in sedimentation due to plowing of nearby fields are subject to regulation by the Army Corps of Engineers. Yet, specified routine actions, including most common agricultural practices, are automatically permitted by the regulations (Myhrum). More significant actions, such as draining a marsh to make land tillable or interfering with a natural aquifer, must be under a permit issued by the Corps.

In many parts of the United States, draining or filling wetlands has been a popular way to increase farm acreages or reduce impediments to farm machinery. Through its power to regulate interstate commerce, the federal government has assumed the right to control any significant alterations or pollution in natural wetlands. Landowner rights have been reduced correspondingly. Significant externalities imposed by commercial activities on users of wetlands can be controlled within the new rights arrangements.

Farmland Preservation

As of 1979, 48 states and more than 200 counties had enacted programs to encourage owners to keep land in agriculture (Wilson). Most state programs include preferential property tax assessments for farmland. Some states, rather than utilizing differential assessments, give income tax credits for property tax payments. In a few cases, tax relief is tied to long-term agreements to keep land in agriculture. Farming is being viewed increasingly as a special class of land use. Several rationales have been offered for this new view (Gardner): (*a*) to assure food and fiber for growing national and world populations; (*b*) to maintain viability in local agricultural economies; (*c*) to maintain open space and other environmental amenities; and (*d*) to promote more efficient and orderly urban development. By placing agricultural land in a special class, further steps can be taken to reflect the value to society of farmland retention and to redress policies (such as estate and capital gains tax provisions) that contribute to conversion to nonagricultural uses. As a result, new benefits are available to agricultural landowners. These benefits often are associated with new responsibilities. In Wisconsin, for example, farmland owners are eligible for an income tax credit for property tax payments only if they sign preservation contracts or are included in exclusive township or county agricultural zones (Johnson).

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[3] To 1979, eleven states had enacted programs to protect wetlands, using police power regulation (Myhrum). These state actions were independent of federal wetlands regulations. However, the federal regulations may be administered in part by qualifying states.

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Though Wisconsin's program is an extreme case, farmland preservation programs generally create new opportunities for farmland owners. These opportunities are defined in terms of rights. Attached to these rights are benefits and obligations. In most state programs, the obligations are imposed only on willing landowners. However, Wisconsin's program and several others can lead to involuntary inclusion via zoning. The momentum of state programs is clearly toward requiring more obligations in return for rights to tax reductions and other benefits. Increasingly, owners of agricultural land will choose or be required to assume new opportunities and obligations flowing from farmland preservation programs.

A Property Rights Framework

A more precise understanding of the nature and importance of property rights will help to explain the land use reforms described above. The framework developed by Calabresi and Melamed is helpful. In their framework, a right ("entitlement") confers favor among individuals or groups making competing claims to an object or privilege. It clarifies the relationships among the competitors. Rights are the basic institutional ingredient in the allocation of scarce resources. In defining rights, two matters must be decided: (*a*) initial ownership (allocation) of rights; and (*b*) rules under which they may be exchanged. Collective enforcement of both the initial allocation and the conditions for exchange is required if a legal system is to have meaning.

The allocation decision, according to Calabresi and Melamed, must reflect accepted tenets of social relations, including distributional equity and judicial consistency. Within these constraints, an entitlement should be made to the party best able to evaluate its social worth or, secondarily, to the party who can act most cheaply to correct errors in its initial allocation (i.e., evaluate and initiate exchange). Where competing parties are equally able to evaluate an entitlement and initiate exchange, where transactions are costless, and where income effects are negligible, the exchange equilibrium is invariant to the initial allocation of rights (Coase). In reality, income effects often are not negligible, and competing parties are not equally equipped to trade (Samuels, Mishan). An important case of unequal trading abilities arises when an object or privilege has a collective dimension—many individuals have interests in its use. A farmer whose soil losses contribute to siltation of nearby streams and water supply reservoirs cannot contact all persons who use the streams or drink the water. Nor is he or she able to look beyond productivity losses to evaluate the social costs of the lost soil. On the other hand, a government acting on behalf of the citizenry may evaluate the external social cost and initiate transactions with the farmer.

The second matter in assigning rights is the conditions of their exchange. Three options were noted by Calabresi and Melamed: (*a*) property rules, (*b*) liability rules, and (*c*) inalienability. With property rules, consent to an exchange must be given in advance by all parties at an acceptable price, like market transactions. Beyond the government's presence in setting and enforcing rules of fair exchange, neither the price nor the willingness to exchange is subject to direct government control.

Under liability rules, prior consent to an exchange is not required, and prices are set by an objective third party, such as a court. Damage claims following an auto accident illustrate transactions suited to liability rules. Government involvement is increased here, relative to property rules, because affected individuals are not likely to agree to a rate of compensation without the threat of arbitration. In other situations, liability rules may be appropriate because many individuals with interests in a transaction are not efficiently represented in the market. Assessment and representation of those interests by an objective authority (government) may be cheaper than negotiating separately with each one. This logic is behind eminent domain condemnation of property for public uses and in the levying of effluent charges.

Finally, inalienability disallows exchange of specified rights under some or all circumstances. The state controls both transactions (by prohibitions) and prices (e.g., fines and prison terms). For example, free speech, bodily integrity, and freedom from peonage are protected in this way in the United States.

In general, property rules are well-suited to exchanges for which social values are easily established and holdouts or freeloaders do not make evaluation unduly complicated. Liability rules are appropriate where many individuals are affected by a transaction and incentives to distort preferences are present. Finally, where collective values are so high that few individuals will want to pay the cost of a transaction, inalienability is suitable. Inalienability also may be invoked in cases of overwhelming moral or ethical interests.

Property Rights and Characteristics of Interactions

Property rights must reflect relevant human values and characteristics of specific human interactions. Bromley identified six "attributes of human interdependence" which might be crucial in allocating and protecting rights: (*a*) the nature (e.g., irritating or life-threatening) of the impact; (*b*) the frequency of the impact; (*c*) third-party effects; (*d*) transaction costs; (*e*) whether or not a unique damage function exists; and (*f*) whether or not the impact is reversible. For example, interactions posing irreversible health risks to many individuals, such as the release of toxic pollutants into watercourses, are not amenable to private negotiation yet have high costs to society. Providing liability or inalienable protection to the general public against such transactions is likely to be the least costly solution. Soil erosion, while involving many "victims," does not pose the significant and immediate risks associated with toxic pollutants. In most states, farmers are now protected with property rules under which erosion control may be "purchased" through state or federal technical and cost-sharing aid. Iowa's requirements for erosion control depart from the norm only by using liability rules; even there, the farmer is protected.

Constitutional Limitations

Efforts to tailor agricultural land use rights to human values and interactions are subject to constitutional limits. These limits define the line between legitimate government actions taken in the public interest and those that remove or limit private rights without justification (Bosselman, Callies, Banta). The three main powers used by governments to accommodate the public interest are eminent domain, police power, and power of the purse (Bock). According to the fifth amendment to the Constitution, eminent domain proceedings must entail "just compensation" for property taken for public use.

Police powers are used to promote public health, safety, morals, or general welfare. The scope of police power has been described as being as broad as the public welfare or necessity. It is "one of the least limitable" governmental powers (Bock, p. 110). The tenth amendment to the Constitution allocates most police powers to the states. However, federal powers are rather broad. For example, federal powers over interstate commerce have been used to justify federal authority over wetlands and pollution (Finnell). Many powers are allocated in state laws to local jurisdictions. Zoning and other land use regulations rely on state police powers but are locally administered.

Spending for voluntary conservation is a clear example of governmental fiscal powers. The property tax advantages given to agricultural landholders in many states and tax incentives for investments in pollution and erosion control equipment are other examples.

Despite constitutional limits, much leeway remains both in defining the public welfare and, hence, legitimate public activities and in allocating powers among governmental units. Of particular importance is the constantly changing perception of constitutional limitations on public actions. This phenomenon is especially apparent in times of war and other crises, such as the dust bowl of the 1930s. It also is visible in long-term trends such as the continuing heightened public awareness of environmental problems in recent decades. In general, as public affairs change, rights are reconsidered and adjusted to suit new public purposes. Rights in agricultural land are not immune from this process.

Changes in Interactions

One purpose of this paper is to explain some changes of rights in agricultural land occurring today. Those rights should be altered as human interactions or values relating to agricultural land change and grow more complex (Carmichael). Apart from temporary crises, what forces impel changes in human interactions relating to land?

Economic relations involve consumption and production. The latter combines capital, labor, technology, and natural resources. Population composition and organization determines consumption demand. Hence, population composition, technology, and the natural resource base determine patterns of human interaction. Of these population and technology are dynamic forces for change (Demsetz; Grove; Ruttan 1978, 1981).

Population changes are significant in at least four ways: (*a*) A growing population contains more individuals with demands or rights which are collective in nature and increasingly costly to evaluate. (*b*) An increasingly affluent population will make its income effects felt. These may be quite different from the substitution choices of a static economy. (*c*) An increasingly urban population will value rights in agricultural land differently from a society which is mainly rural. (*d*) Shifting coalitions alter the political balance.

Technological developments generally enable us to make better use of abundant factors of production while reducing dependence on scarce ones. Technological change also contributes to our growing understanding of all ramifications of production and consumption, in particular waste products and external impacts.

Some Emerging Property Rights in Agricultural Land

What has happened in recent years to prompt a reconsideration of rights to use agricultural land? Demographic changes have been important (Penn). They include (*a*) increases in national and world population bidding for U.S. agricultural commodities, and (*b*) a decrease in the number of people having direct (ownership or working) relations to U.S. agricultural land. The first change will exert great pressure to increase U.S. agricultural production within the next fifty years (USDA 1980b, p. 14). It already has ended the days of abundant inexpensive farmland. The second development has diminished political power exercised by rural landowners. In addition, it means a larger proportion of the U.S. population is a "victim" of agricultural externalities. Internalizing those externalities imposes costs on nonfarm people indirectly at the grocery store. Together, these changes have increased social costs relative to private costs of farmland use. The political power to deal with these cost disparities has increasingly flowed toward nonfarm groups.

Technological changes also have been important. Heavy use of chemicals, crop monoculture, and adapting land to the requirements of large machinery have led to chemical pollution, soil erosion and nutrient depletion, cultivation of marginal acreage and former wetlands, and destruction of terraces and other soil management devices. Hence, external costs have increased. At the same time, we have become better able to recognize, monitor, and evaluate external impacts of farming. We have far to go in assessing these impacts, but our current knowledge suggests the needed policy changes and the associated transactions costs.

Soil Conservation

Upgrading existing voluntary conservation programs entails no fundamental change in the means of protecting rights. Purchasing conservation performance is illustrated by a number of different proposals. One is to pay farmers to implement specific management practices or, more ideally, to reduce soil erosion to tolerance levels. This approach entails a more significant exchange than under cost sharing; a right actually changes hands following a payment to the landowner. The contractor (perhaps a state agency) would hold an enforceable right for the duration of the contract. This kind of exchange requires an elaboration of property rules which govern rights to lose soil. However, neither a fundamental shift in the rules nor in the initial allocation is implied. Purchasing conservation performance already exists in the "long-term agreements" (three to ten years) which the USDA requires for some kinds of conservation cost sharing. Rather than stipulating minimum results to be attained, these agreements simply require that the investments be maintained.

A second purchase option is "cross-compliance." Actually, there are two approaches to cross-compliance (Benbrook): (*a*) The "green-ticket" strategy (also called "conservation incentives payments") would boost commodity price support payments for farmers who agree to undertake conservation practices. (*b*) The "red-ticket" strategy would penalize noncomplying landowners for excessive erosion by reducing or revoking commodity price support payments for which they otherwise would be eligible. This would not change the rules governing soil erosion rights, but it would reduce their value.

Iowa's regulatory approach to soil erosion has changed the method of exchanging erosion rights but not their allocation. Owners or occupiers of Iowa's land can be required to take steps to reduce erosion, but financial and technical assistance must be provided by the state in such cases. The landholder remains entitled and is protected by liability rules under which partial compensation must follow interference with individual rights. Precedents exist, in a few soil conservation districts and counties, for more stringent government controls on rights to lose soil. However, these precedents do not appear to be affecting current changes in state and federal policies.

The new generation of soil conservation policies is not likely to shift rights in agricultural land dramatically. In most cases, they are likely to involve refinements in the definition of rights to lose soil and, in extreme cases, to govern exchanges of those rights with liability rules rather than property rules. A reallocation of rights away from landowners would entail prohibitively high costs of enforcement on every parcel of affected land. Individual landowners can more easily initiate transactions over soil loss rights than governments. On the other hand, private values of erosion are now significantly divorced from social values. At a minimum, the disparity is cause to increase the private value of erosion. This could be achieved through cross-compliance or contractual payments. These options entail no fundamental changes in the allocation or protection of rights. In practice they may require federal involvement, especially in cross-compliance. Another way of injecting a greater public interest in erosion rights is to shift to liability exchange protection, as Iowa has. This approach has the advantage of allowing government to take actions where voluntary cooperation is not forthcoming. Federal participation is not needed. Yet, rights holders are compensated for state actions that curb their soil erosion rights.

Water Quality

Programs to reduce agricultural nonpoint pollution involve several aspects of land use rights. Within the general structure of federal water pollution control statutes, states vary widely in their approaches to nonpoint pollution.

One aspect is the application of chemical products. Rights to use some products, such as DDT, have been severely curbed. In effect, collective ownership has been asserted and exchange disallowed. These rights may be monitored at points of chemical production and distribution with modest transaction costs.

A second aspect concerns soil and land management—tillage practices, contouring, crop rotation, etc. This is the main focus of Section 208 rules and guidelines. Transactions over rights to make these decisions would be quite costly. Each parcel of land has a unique potential for contributing to pollution. A reallocation of rights away from landowners would be exceedingly costly to enforce. Most states have steered away from such a course, choosing to reemphasize and reinforce voluntary programs.

Most state water quality programs emphasize sedimentation relative to other kinds of agricultural pollutants. Too little is known about many other agricultural pollutants (e.g., nutrients and organics) to allow a careful assessment of associated social costs and benefits. In such cases, states are understandably reluctant to generate costly additional information or to redefine rights without compelling evidence. The federal government has been gathering additional information on agricultural pollutants. As it becomes available, states will be able to extend the refinement of farmland use rights as they affect pollution. Some refinements may involve nonproperty rules for exchange. However, where rights can be exercised only by individual landowners (as opposed, say, to chemical producers) the presumption toward individual ownership will remain.

Wetlands Protection

The destruction or pollution of wetlands is a problem with similar causes as nonpoint water pollution and soil conservation—more nonfarm people exist to place value on nonfarm uses of wetlands for hunting, fishing, and wildlife habitat. Advanced farming methods have made wetlands conversion desirable to farmers. The supply of wetlands has clearly declined. The marginal social value of wetlands (e.g., for wildlife habitat) has greatly increased in response to these trends.

The growing disparity between owners' and society's evaluation of wetlands has prompted significantly more pronounced changes in rights than for soil conservation or nonpoint pollution. Section 404 of the Clean Water Act formally allocated to the federal government rights to control actions having severe or lasting impacts on wetlands. Rights to control specific routine agricultural or other practices having moderate or temporary impacts on wetlands were assumed by the government, but then reallocated to individual landowners. This arrangement recognizes the high costs of monitoring such activities.

The rights held by the federal government are protected with property rules, with the government acting as the negotiating agent of the general public. An individual or group may apply for a permit to undertake a wetland alteration project. Aside from application fees, applicants must provide assurances that the project does not impose undue social costs. In effect, payment for the permit comes from net social gains realized from the project. These presumably accrue mainly to the applicant.

Why were wetland rights reallocated to government? One explanation is that enforcement costs of such an arrangement are reasonable because (*a*) wetlands are relatively easily identified and much more limited in extent than general agricultural land, and (*b*) the net reallocation did not include minor impacts which, if subject to permits issue, would clog administrative channels. Government could reasonably expect to monitor and enforce its major claims. Furthermore, anticipating wetlands problems is more important than with soil erosion or nonpoint pollution. Wetlands conversion is often irreversible while erosion is usually gradual, and most pollutants biodegrade or "flush out" of ecological systems. Vesting individuals with rights would not meet the anticipation problem. The government would have to know who was planning wetlands projects and, under property rules, offer to pay the parties to forego the project or, under liability rules, invoke an injunction while paying compensation. A lower-cost arrangement, embodied in current regulations, is to place responsibility for initiating the exchange of rights on individuals who seek a significant wetland alteration.

Farmland Preservation

Programs to preserve farmland concern agriculture as a general land use as opposed to management practices within agriculture. The major theme of farmland preservation programs is to enhance private values attached to agricultural land use rights.

These programs, like those for soil erosion and nonpoint pollution, must contend with wide variation in local conditions. The high cost of centralized management and the enforcement of rights to convert land to nonagricultural uses support the concept of individual ownership. Usually, property rules are employed to arrange exchanges. Landowners can accept or reject whatever tax relief plans are offered by state governments. With zoning, however, unwilling property owners can be caught in the majority's decision to establish an agricultural zone. In such instances, rights may be taken away from unwilling landowners. Tax relief is compensation in such cases with the transaction resembling private ownership of rights with liability rules governing exchange.

Conclusions

Changes in rights exercised by individuals in a lawful society are a natural part of the social evolution. As the wants and needs of populations evolve and as new technologies emerge, then social and private values attached to rights are bound to change. Rights in agricultural land are no exception to this process. We have seen great increases in the complexity with which these rights are defined. On the whole, society is well served by the liberal allocation of rights to farmland owners. The costs of monitoring and enforcing other arrangements would be prohibitive. Exceptions to this pattern are likely to occur where relatively little, easily identified land is involved, as with wetlands regulation.

Much more change is apparent in the rules governing the exchange of rights. Where a reallocation of rights in response to new problems would be too costly or inconsistent with prevailing judicial sentiments, liability protections are attached to individuals' rights. This provides a mechanism by which the public interest can be served while providing fair compensation to owners whose rights are exchanged by fiat. It retains the flexibility of individual ownership and is consistent with the national ethic of maximum individual liberties consistent with the general welfare. It also reflects a growing awareness that the general welfare depends on wise use of agricultural land.

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Commodity Programs and Control Theory

James W. Richardson and Daryll E. Ray

The decision-making process for commodity programs in the United States is cast in terms of adaptive control theory, following the control framework outlined by Rausser. It is argued that the actual commodity program decision-making process can be viewed as a sequential multiperiod control problem and that multiple period, open-loop feedback control of a disaggregate policy simulation model can be used to assist agricultural policy makers. The empirical results present the first-round application of a suggested sequential use of control techniques and demonstrate the feasibility of applying control procedures to a multicommodity, agricultural policy simulator.

Key words: optimal control theory, perturbation analysis, simulation, U.S. agricultural policy.

Rausser's recent *Journal* article adeptly frames the general policy evaluation problem within the adaptive control theory context. Rausser's general model incorporates uncertainty and learning as well as the integration of econometrics, systems analysis, simulation, and optimization. Adaptive control provides a general framework for optimal policy decision making in a dynamic setting.

This paper focuses on the use of control methodology for commodity program administration. The actual decision-making process for setting commodity policy (or control variables) is described using the passive learning version of adaptive control theory. To be of practical use, applications of this process should allow parameter change (via learning) through time and updating of other information. However, the adaptive aspects need not be prespecified by internal mathematical relationships. Corrections can be based on information obtained from the actual system. A model-based control application is presented to illustrate a model which allows multiple controls. It includes the major agricultural commodities and could accommodate adaptive learning in policy analysis.

Control Theory as a Concept

Commodity program administration can be described broadly as an adaptive control problem. The controls or policy variables are loan rates, set-asides, and target prices for major crops such as feed grains, wheat, and cotton. The state variables include information normally found in supply and utilization tables, livestock production, prices, incomes, and other aggregates. Agricultural prices, net income of crop and livestock producers (or rate of return to farm resources), rates of food and general inflation, and treasury costs are possible performance indicators of selected controls. Control variables are set to optimize a preference function or performance measure over the decision horizon. A multiperiod horizon is required because current control variables affect, and are affected by, future levels of economic variables. Also, feed-price impacts of commodity programs on the livestock economy, consumer food costs, general inflation and other measures require time for realization. Hence, the decision making process is a feedback control problem because information about the prospective state of the system over the entire planning horizon (say five years) influences, and is influenced by, the controls from the first through all periods of the decision horizon.

As Rausser stresses, the decision-making process is full of uncertainties. Some of these

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uncertainties are inherent to the agricultural production process, particularly domestic and worldwide weather. Other uncertainties relate to farmer and market responsiveness to announced policies. Forthcoming information on crop yields, farmer response to announced policy instruments, and the accumulation of other data allow for passive learning, revisions of policy variable levels, and changes in farm policies in succeeding years. The relative weights on performance variable targets could be affected by inflation, trade balances, and government outlays. Thus, control values chosen in period 1 for each period in the planning horizon are based on the knowledge that corrections can be made in the future. The corrections made in period 2 (but covering periods 2 through T) are based on realized observations in period 1. Control variable corrections also reflect what has been learned about farmer and market responses to previous control levels. Parameters can be reestimated prior to making annual corrections to take advantage of the additional data. The various analyses are recalculated, corrections are made in the control variable values through the end of the planning horizon, and policy variable values for period 2 are announced. This process is repeated annually throughout the remaining years of the planning horizon. A rolling horizon of length T is actually more relevant than a fixed or endpoint horizon.

Control Modeling

Although control theory provides a valuable conceptual framework for summarizing the decision-making process, it is better known as a mathematical construct for controlling a scaled-down model of an actual system. A descriptive model of the (economic) system is selected or built, control variables are identified, and a preference or criterion function is selected. The sophistication of the control mechanism used in analyzing a decision problem depends on the nature of the problem and the decision-making process. The U.S. Department of Agriculture (USDA) periodically develops short-term (three to five years) projections of supplies and utilizations for major U.S. commodities including prices, incomes, and other measures. Commodity specialists in USDA develop these projections using formal and informal forecasting models tempered with their own judgments. The projections reflect explicit assumptions concerning changes in population, per capita incomes, consumer preferences, export demand, technology (crop yields and livestock gains), other supply and demand shifters, and prospective commodity programs. These estimates provide reference, or baseline, data for policy analysis.

From a control-modeling standpoint, the baseline data provide tentative paths for the controls and state variables over the T-period planning horizon, but without an explicit criterion or preference function. The existence of these baseline data suggests the use of a perturbation control scheme. Using the baseline data as the regular or expected course of motion for the agricultural system, a new course of motion can be obtained by perturbing the system with small changes in the policy variables and tracing their impacts on the state variables.

Following Rausser, the perturbation application would be adaptive if a mechanism is included which endogenously reestimates the joint density distribution of the model parameters. Parameter reestimation is required for both passive and active learning formulations. With active control, the criterion function includes terms which allow additional information on the parameters to influence the selection of the control values (Rausser pp. 480–2).

In this study, a T-period perturbation analysis is used, but parameter learning is presumed to occur outside the empirical model. The intent is to integrate control solutions into the existing information and policy-making process. The annual policy-making process begins with the development of a three- to five-year baseline by USDA analysts. The next step is the application of a multiperiod, open-loop feedback control model. The model uses perturbation analysis to rechoose control paths to optimize a specified preference function. In general, each control value is influenced by expected future values of the state variables. For example, suppose the performance measure is penalized if annual ending-year stocks fall below specified levels. Selected values for loan rates, land diversions, and other controls for periods 1 through T take into account expected carryover levels in period T (and periods 1 through $T - 1$). Hence, a surge in expected exports the last two years of the planning period (due, say, to anticipated increases in real incomes of importing countries) would affect control values over the entire planning horizon.

The remainder of this paper illustrates the initial round of activities suggested by the foregoing control interpretation of the commodity program decision-making process. A multiperiod, open-loop feedback control model is used to assist the actual, adaptive policy-making process. This approach incorporates the adaptive nature of the policy-making process without requiring the empirical model to be adaptive.

Specification of the Control Problem

The control formulation is written specifically for the first year's application of the adaptive policy-making process described in the previous section. A corresponding specification would be used for each year's application with a rolling T-period planning horizon. The model contains nonlinear behavioral relationships and inequality constraints on both the control and state variables. A commodity disaggregated agricultural model, which allows cross commodity interactions, is used. Due to nonlinearities, the model is solved in its structural (rather than reduced) form with a numerical optimization procedure.

The objective of optimal control is to find control variable values that optimize the criterion function, taking into account the linkage between and among the control and state variables.[1] Let N be the number of controls and K be the number of state variables. Let W be a real valued function of M of the state variables, termed output variables; W provides a scalar measure of system performance for each period in the T-period planning horizon.

The general formulation can be stated as follows: find the N-dimensional control path that maximizes

$$J = \sum_{t=1}^{T} W[\mathbf{y}_K(T - i), \mathbf{r}_E(t)],$$

subject to

$$\mathbf{y}_M(t) = F[\mathbf{y}_M(t - i), \mathbf{x}_P(t - i), \mathbf{u}_N(t)], \text{ and}$$

$$\mathbf{u}_N(t) \epsilon R_N(t),$$

where $i = 0, 1, 2, \ldots, T$; $\mathbf{y}_K$ is a $K \times 1$ vector of output variables; $\mathbf{r}_E$ is an $E \times 1$ vector of parameter weights associated with the functional forms of the output variables; $\mathbf{y}_M$ is a $M \times 1$ vector of state variables (K is less than or equal to M); F is the mathematical system to be controlled; $\mathbf{x}_P$ is a $P \times 1$ vector of uncontrolled exogenous variables; $\mathbf{u}_N$ is an $N \times 1$ vector of controls, and R_N is the region to which the controls are constrained. Specifics on the behavioral model, the control variables and their constraining regions, and the criterion function are presented in the following sections.

Numerous numerical optimization techniques are available for applying optimal control theory to an existing mathematical model (Box; Fair; Kuester and Mize; Broyden; Swann 1972, 1974; and Goldfeld, Quandt, Trotter). The technique used in this study is Box's Complex Procedure. It was selected because it can handle many control variables in a dynamic, discrete-time system, allows for open-loop feedback control, and permits nonlinear inequality constraints on the controls. In addition, Complex has been used successfully to optimize large-scale simulation models (Adelman and Steven; Friedman and Pinder; Mitchell and Kaplan; and Umeda, Nishio, Komatsu).

Complex is a sequential search algorithm that maximizes a criterion function subject to constraints on the control variables. Initial control path values are selected at random from admissible ranges. These initial paths are used as input in a computer simulation model of the system being controlled to develop values for the state variables and criterion function. The control path associated with the minimum value for the criterion function is replaced and a new control path selected by reflecting the rejected control path through the centroid of the remaining control paths. If a new control variable violates its upper or lower bound, it is reset just inside the violated bound. The model being controlled is solved for the new control path to determine its associated values for the state variables and criterion function. Again, the control path corresponding to the minimum value for the criterion function is rejected and a new control path generated and tested. The process is repeated until convergence is obtained. Convergence occurs when five successive evaluations of the criterion function are within a user-specified degree of accuracy. Since Complex is a heuristic search, one must resolve the problem several times with different starting values for the controls to insure that a global optimal has been identified. (A source listing of Complex is available in Kuester and Mize, pp. 368–85.)

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[1] Precise mathematical definitions of optimal control theory are available in Johnson and Rausser, Burt, Intrilligator, Dorfman, Chow, and Kirk.

Model of the System

A model of the agricultural economy useful for policy control analysis should include behavioral relationships for the major crop and livestock categories and should explicitly incorporate a wide array of policy instruments. The opportunities for substitution in crop production and utilization and lagged effects of crop prices on the livestock and consumer sectors preclude separate commodity-by-commodity analysis.

The U.S. Department of Agriculture cosponsored the development of a perturbation model which was used for this study (Ray and Richardson). The National Agricultural Policy Simulator (POLYSIM) includes the following crop and livestock categories: feed grains, wheat, cotton, soybeans, cattle and calves, hogs, sheep and lambs, chickens, turkeys, eggs, and milk. The POLYSIM model uses a reference baseline for the initial supply, utilization, and prices of these commodities. Changes are made in the policy instruments (loan rates, set-aside, target prices, etc.), and their impacts are traced through the system by adjusting the individual baseline production and utilization values for percentage changes in prices, from their baseline values, weighted by own- and cross-price elasticities. The model begins by simulating the production of each livestock category as a function of lagged livestock and feed prices. Supply shifters such as herd and flock sizes implicit in the baseline for each year of the planning horizon are assumed to remain constant. Baseline prices for seven livestock categories are adjusted to reflect the percentage change in livestock available for domestic consumption, weighted by the George and King price flexibility matrix.

Baseline values for harvested acres and yields are adjusted to reflect percentage changes in lagged crop prices and appropriate policy variables. Crop supply is the sum of production and carry-in. Prices for the crops are determined by the level of supply relative to expected demand. Actual quantity demanded is a function of price and other variables. It is assumed that demand shifters (such as population, per capita incomes) are unchanged from those implicit in the baseline for demands other than livestock feed. Livestock feed demand is derived from livestock production, feed costs, and livestock prices.

Several measures of aggregate farm income and government payments are computed by the model. Total receipts is the sum of cash receipts for all crops and livestock plus total government payments. Total government payments to farmers is the sum of set-aside payments, deficiency payments for all crops, and other direct government payments to farmers. Realized gross farm income is the sum of total market and government receipts and total realized non-money income. Realized net farm income is the difference between realized gross farm income and total farm production expenses. After solving these identities, the model repeats the simulation loop for the next year in the planning horizon. The model is recursive because values calculated in period t are used as exogenous values in period $t + 1$.

The impacts of alternative policy variable levels on production and supply and utilization components for each commodity, as well as on aggregate farm incomes, consumer food expenditures, and government costs can be simulated with the model. The policy instruments include target prices, loan rates, alternative Commodity Credit Corporation (CCC) buy-and-sell provisions, acreage allotments, voluntary or mandatory acreage set-aside or diversions, per acre payment schedules for voluntary acreage diversions, and acreage or production quotas.

Control Variables and Boundaries

The policy instruments used as control variables are annual loan rates and voluntary acreage diversion levels for feed grains, wheat, and cotton over the 1978–81 period. The annual values of control variables for the three crops over the 1978–81 planning horizon amount to twenty-four controls. Where possible, the Food and Agriculture Act of 1977 was used to designate feasible ranges or boundary constraints for the control variables. The lower boundaries for wheat and corn loan rates are set at the legal minimums specified in the 1977 Act (table 1). The upper boundaries are the estimated target prices initially authorized by the 1977 Act. The maximum set-aside acreage levels were set at 35% of the 1977 harvested acreages for wheat and feed grains and at 28% of 1977 harvested acreage for cotton (table 1).

Table 1. Feasible Ranges for the Control Variables, $R_n(t)$

	Wheat		Corn		Cotton	
Year	Lower	Upper	Lower	Upper	Lower	Upper
	Loan Rates[a]					
	($/bu.)				($/lb.)	
1978	2.00	3.00	1.75	2.10	.37	.52
1979	2.00	3.16	1.75	2.21	.37	.52
1980	2.00	3.34	1.75	2.34	.37	.58
1981	2.00	3.52	1.75	2.47	.37	.61
	Effective Annual Acreage Diversions[b]					
	(million acres)					
1978–81	0	14.9	0	22.6	0	1.9

[a] The lower limits for wheat and corn are specified in the Food and Agriculture Act of 1977. The proportion of minimum to announced 1977 loan rate for wheat was used for cotton. Upper boundaries are estimated target prices.

[b] The upper limits for cotton are based on 1977 harvested acreages, the maximum cotton set aside allowed by the 1977 Act, and a 40% slippage rate. After accounting for slippage and crop differences, the effective diversion limits are set at 17% of 1977 harvested acreage for cotton and 21% of harvested acreages for wheat and feed grains (corn, grain, sorghum, oats and barley). Slippage is the portion of diverted acreage that does not result in reduced production.

Criterion Function

One of the most challenging aspects of using control theory for policy analysis is choosing an appropriate criterion function (Burt). The sum of consumer and producer surplus provides a direct measure of social value. However, for this study we decided to optimize a function consisting of key variables policy makers are accustomed to working with. This approach has been used by Rausser and Freebairn (1974a,b), Bray, and Livesey. The state (or output) variables included in the criterion function are (*a*) two farm income variables (which are conditionally maximized), (*b*) government farm program expenditures, (*c*) consumer food costs, and (*d*) ending-year stocks of feed grains, wheat, and cotton (to represent taxpayer and consumer interests). Realized net income and net returns to livestock producers are the farm income variables conditionally maximized.[2] Government expenditures for direct payments to farmers and for CCC interest and storage cost appear separately in the criterion function. Identification of the eight output variables in the criterion function corresponds to the first of a three-stage specification approach suggested by Rausser and Freebairn (1974b).

The second stage of the Rausser-Freebairn approach is to specify the mathematical form of the criterion function. A widely used form is Theil's quadratic preference function. With Theil's criterion function, the control path is selected which minimizes the deviations between targeted and realized output values in the tth period. However, Friedman points out that policy makers typically recognize politically acceptable ranges on output variables rather than target values (pp. 183–91). He proposes a piecewise quadratic function where the targeted values are replaced by politically acceptable upper and lower bounds. The criterion function selected for this study maximizes farm income subject to constraints imposed by a piecewise objective function for the included non-income output variables. The criterion function can be expressed as:

if the lower bound of the specified range is violated—

$$(1) \quad jl_m(t) = r'_m(t)|y_m(t) - lb_m(t)|^2, \quad \text{and } ju_m(t) = 0;$$

if the upper bound of the specified range is violated—

$$(2) \quad ju_m(t) = r''_m(t)|y_m(t) - ub_m(t)|^2, \quad \text{and } jl_m(t) = 0;$$

$$(3) \quad \text{maximize } J = \sum_{t=1}^{4} \{nfy(t) + nly(t) + \sum_{m=3}^{M} [jl_m(t) + ju_m(t)]\};$$

where $r'_m(t)$ and $r''_m(t)$ are weights for output variable y_m violating its lower and upper boundaries, lb_m and ub_m, respectively, in period t[$\mathbf{r}'_m(t)$ and $r''_m(t)$ are two elements in the $E \times 1$ vector $\mathbf{r}$ as defined earlier for the t-time period]; $nfy(t)$ is the level of realized net farm income in period t, and $nly(t)$ is the level of net income for livestock producers in period t, defined here as total livestock cash receipts less variable production expenses for livestock. The positive sign preceding the interior summation in (3) is used to accommodate both positive and negative $\mathbf{r}_m$ values in (1) and (2), thus making the summation decrease the value of J if r_m is less than zero and increase the value of J if r_m is greater than zero. No ranges are specified for the income variables (*nfy* and *nly*). With both maximization and penalty terms included in the criterion function, a constrained maximization occurs. If the weights associated with the penalty terms are not overwhelmingly large, the constraints may not be absolute. They may allow trade-offs among constraints and variable levels being maximized.

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[2] Net income for all livestock (about $18 billion per year) is included in the performance measure to prevent the control mechanism from increasing net income for the crop sector without regard to the livestock sector. Farm programs that support feed prices at high levels result in high costs of feedstuffs, which immediately reduce the net incomes for livestock producers causing cutbacks in livestock production in the following years.

The final stage in specifying the criterion function is to estimate parameter weights for the output variables [$r'_m(t)$ and $r''_m(t)$]. Bray suggests that the parameter weights may be determined in interviews with decision makers and planners. Rausser and Freebairn (1974b) include Bray's method and add two others: (*a*) the indirect (or revealed preference) approach, which involves study of past decisions and (*b*) the arbitrary approach, in which the analyst simply assigns values for the parameter weights based on his/her understanding of the system. With the criterion function used here, the analyst also must identify ranges of acceptable values for the output variables for each period. This is less demanding than alternative formulations which require single-valued targets.

Hypothetical ranges and parameter weights for the output variables used in this study are in table 2. The ranges and parameter weights only illustrate plausible values for agricultural policy analysis. The parameter weights probably are not constant over the planning horizon, but for simplicity of demonstration are assumed so. The true weights could be either a function of time or nonlinear.

Baseline values for consumers' total expenditures for food, estimated by commodity analysts in USDA, are used as lower boundaries, $lb_3(t)$. The upper boundaries, $ub_3(t)$, are set at 101% of the baseline values. The baseline assumes a per capita increase in food expenditures of 3%–4% per year so the 1% increase for the upper boundaries results in an acceptable annual increase of 4%–5% over the planning horizon.

The illustrative parameter weights for consumers' total expenditures for food, below and above the designated ranges, are +2.0 and −2.0, respectively. The weight of −2 for the upper boundary suggests that a policy resulting in a $1 increase in total consumer food costs would have to be accompanied by a $2 increase in farm income to maintain total satisfaction for society, *ceteris paribus*. The +2 weight for the lower boundary implies indifference to a $2 decline in farm income if consumer food expenditures increase by $1. Therefore, the level of the performance measure increases when policy actions lead to reduced food costs and unchanged or higher net farm incomes. Weights outside the range of ±1 were selected to recognize the lobbying strength of consumers relative to representation of production agriculture. Ideally, the weights should reflect society's marginal rate of substitution between net farm income and food costs.

The lower boundaries for direct government payments to farmers $lb_4(t)$, are set at the baseline estimates of government payments for miscellaneous farm programs, which exclude deficiency and diversion payments for wheat, feed grains, and cotton. Upper boundaries, $ub_4(t)$, are set at $3,700 million. The designated range for CCC storage and interest cost is zero to $600 million. The upper value equals the estimated storage and interest costs for holding 30 million ton feed grain and 600 million bushel wheat reserves.[3] The same parameter weights are used for both government expenditure variables, 0.0 and −1.5 for the lower and upper boundaries, respectively. The upper boundary weight was set less than −1.0 to discourage maximizing net farm income by simply increasing government payments to farmers. Theoretically, the weights should represent taxpayers' marginal disutility of a dollar of government expenditure in excess of the upper boundary.

The criterion function also includes year-ending carry-overs of feed grains, wheat, and cotton. Lower boundaries for stocks are set at 30 million tons of feed grains, 600 million bushels of wheat, and 2 million bales of cotton. Upper range boundaries are arbitrarily set at twice the lower boundaries.

Upper boundary parameter weights for ending year carry-overs are estimated to be the costs to society associated with a "surplus carry-over." The cost to society of surplus carry-over is the sum of direct costs (interest and storage charges) and the opportunity costs for the resources used to produce the surplus. The opportunity cost to society for surplus carry-overs is theoretically the area under the supply curve of the excess production. It is

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[3] The CCC reserve levels are based on values reported by Waugh, and Tweeten et al. Waugh recommends a feed grain reserve of 30 to 40 million tons and a wheat reserve of 550 to 600 million bushels. Tweeten, Kalbfleisch, and Lu recommend a wheat reserve of 600 million bushels.

Table 2. Assumed Upper and Lower Boundary Levels and Their Respective Weights for Output Variables

Output Variables$_i$ for Years$_t$	Projected Values by CED Commodity Analysts (Baseline Values)[a]	Acceptable Range		Parameter Weights	
		$lb_m(t)$	$ub_m(t)$	Lower Boundary $[r'_m(t)]$	Upper Boundary $[r''_m(t)]$
Consumers' total expenditures for food ($m = 3$)	($ mill.)				
Year 1	188,300.0	188,300.0	190,183.0	+2.0	−2.0
Year 2	196,800.0	196,800.0	198,768.0	+2.0	−2.0
Year 3	205,000.0	205,000.0	207,050.0	+2.0	−2.0
Year 4	214,000.0	214,000.0	216,140.0	+2.0	−2.0
Total government payments to farmers ($m = 4$)					
Year 1	3,019.0	850.0	3,700.0	0.0	−1.5
Year 2	3,549.0	850.0	3,700.0	0.0	−1.5
Year 3	4,712.0	850.0	3,700.0	0.0	−1.5
Year 4	5,850.0	850.0	3,700.0	0.0	−1.5
Total CCC interest and storage costs ($m = 5$)					
Year 1	150.0	0.0	600.0	0.0	−1.5
Year 2	310.4	0.0	600.0	0.0	−1.5
Year 3	452.0	0.0	600.0	0.0	−1.5
Year 4	599.0	0.0	600.0	0.0	−1.5
Ending year stocks of feed grains ($m = 6$)	(million tons)				
Year 1	70.4	30.0	60.0	−104.0	−82.5
Year 2	82.6	30.0	60.0	−104.0	−82.5
Year 3	87.5	30.0	60.0	−104.0	−82.5
Year 4	89.3	30.0	60.0	−104.0	−82.5
Ending year stocks of wheat ($m = 7$)	(million bushels)				
Year 1	1,539.0	600.0	1,200.0	−3.4	−2.8
Year 2	1,827.0	600.0	1,200.0	−3.4	−2.8
Year 3	2,112.0	600.0	1,200.0	−3.4	−2.8
Year 4	2,374.0	600.0	1,200.0	−3.4	−2.8
Ending year stocks of cotton ($m = 8$)	(million bales)				
Year 1	4.3	2.0	4.0	−284.8	−268.6
Year 2	4.2	2.0	4.0	−284.8	−268.6
Year 3	4.5	2.0	4.0	−284.8	−268.6
Year 4	4.1	2.0	4.0	−284.8	−268.6

[a] Baseline values were developed by the USDA based on information available July 1977.

assumed that the marginal production cost for excess carry-over is the crop's loan rate. Using the announced loan rates in the 1977 Act and the appropriate interest and storage charges, the costs to society for surplus carry-overs of feed grains, wheat, and cotton $[r''_m(t), m = 6, 7, 8]$ are, respectively, −$82.50 per ton, −$2.80 per bushel, and −$278.60 per bale.

The lower boundary parameter weights for carry-overs should be larger (absolutely) than the respective weights for stocks exceeding the designated carry-over ranges. As ending year stocks become smaller, their value to society increases. The lower boundary parameter weights $[r'_m(t)]$ for feed grain, wheat, and cotton ending year carry-overs are −$104.0 per ton, −$3.4 per bushel, and −$284.8 per bale, respectively. The lower boundary parameter weights reflect higher storage costs than the upper boundary weights. This accounts for society's increased marginal value of holding reserves in the face of relatively tight supplies.

Commodity Program Assumptions

The commodity program assumptions and baseline data for the illustrative control application were based on information available in mid-1977. Target price and loan rate provisions of the 1977 Food and Agriculture Act were drawn upon, although the act had not been passed at the time of the study. Congressional specification of the farmer-held grain reserve was not complete and was not included in the baseline data or the control analysis.

Loan rates and land diversion levels, which are set at the administration's discretion within statutory limits, are the control variables. Other assumptions also are required including payment rates for voluntary acreage diversion, slippage rates for diverted acreages, participation rates, and similar program variables.[4] Values for these variables are given in table 3. Target price assumptions are taken from provisions of the 1977 Act and appear in table 1 as upper bounds for loan rates. Values of other exogenous variables are set at their USDA baseline values.

Results

The control procedure sought the four-year control path for loan rates and acreage diversion levels of the three crops, which would maximize the criterion function.[5] Because the baseline data contained carry-over stock and government payment levels well above their target boundaries, the solution mechanism searched for control values which would reduce stocks without jeopardizing farm income or consumer interests. In selecting annual values for the control variables, the feedback mechanism took into account the control's influence on the performance measure in future years of the planning horizon as well as its current period value. Solution values for the controls are given in table 4. Tables 5 and 6 provide solution values and index numbers for selected variables.

The control procedure used acreage diversions to raise crop prices and to reduce ending-year stocks. Relatively low values were selected for loan rates. High loan rates could have been used, of course, to raise farm income and reduce deficiency payments, but the resulting stock levels and storage costs would have lowered the performance measure compared to the use of land diversion. In addition, higher loan rates would have led to positive supply responses. Accordingly, the solution values for loan rates are below estimated market prices for the program crops.

The higher prices increased net farm income and, at the same time, reduced deficiency payments from the baseline by narrowing the

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[4] Program participation and slippage rates are assumed to be constant within the specified bounds for loan rates and diversion levels. Values for these variables were established based on past experiences with the farm program options under consideration and research by Tweeten, and by Garst and Miller. The program participation rates in table 3 would have to be increased if the boundary constraints on loan rates are increased and/or if target prices or acreage diversion payment rates are increased. Program participation rates also are related to the assumed values used for calculating deficiency payments, i.e., the national allocation factor and the program acreages and yields. The slippage rates would require revision if the acreage diversion payment rates are revised.

[5] Additional applications used other control variables. When the voluntary diversion payment rates are used, their values are reduced to where total government payments just equal the upper bound and the acreages diverted are equal to the values reported here. Mandatory acreage set-aside levels are about equal to those reported here. However, net farm income is lower with no government diversion payments. When target prices are used, their values are set at or near their lower boundary constraints to keep government payments within its upper bound.

Table 3. Assumptions for Program Participation Rates, Set-Aside Payment Rates, Slippage Rates, and Program Acreages and Yields for Feed Grains, Wheat, and Cotton, 1978–81

Variable	Feed Grains	Wheat	Cotton
Participation rates (%)	65	80	80
Acreage diversion payment rates (million acres)[a]	53.43	32.23	78.26
Slippage rates (%)[b]	40	40	40
Program acreages (million acres)[c]	76.0	56.9	10.0
Program yields (units/acre)[c]	2.06 (tons)	31.0 (bu.)	480.0 (lbs.)

[a] Average production costs for 1977 were used to estimate 1977 land diversion payment rates for each crop (Senate Committee on Agriculture and Forestry). These values were increased 2% annually to obtain 1978–81 values.
[b] The slippage estimates are based on work by Tweeten, and by Garst and Miller.
[c] These values are used to calculate deficiency payments. Program yields for feed grains and wheat are for 1978 and increase .03 tons per acre for feed grains and .5 bushels per acre for wheat each year through 1981.

Table 4. Solution Values for the Control Variables

Item	1978	1979	1980	1981
Effective acreage diversions				
Feed grains (million acres)	5.9	11.9	11.8	10.7
Wheat (million acres)	14.8	14.9	14.9	14.9
Cotton (million acres)	1.9	1.9	1.8	1.5
Loan rates				
Corn ($/bushel)	1.80	1.82	1.82	1.84
Wheat ($/bushel)	2.18	2.21	2.39	2.39
Cotton ($/pound)	.47	.49	.51	.53

Note: Diverted acreages are zero in the baseline. Baseline loan rates are $2.00 for corn, $2.35 for wheat, and $.51 for cotton in all years.

margin between target prices and market prices. The farm program specification analyzed here provided payments to farmers for land withdrawal, offsetting part of the savings from reduced deficiency payments. Government payments were less than the $3.7 billion upper bound imposed on the criterion function for all but the final year (table 5). Additional land diversion could not be used to reduce deficiency payments in the final year since the maximum wheat diversion had been reached, cotton deficiency payments were already zero, and additional feed grain diversion would have led to higher feed grain prices and lower livestock producers' incomes.

The acreage diversions reduced year-ending stocks to within designated ranges. Feed grain stocks were reduced 15% to 30% from their baseline levels to bring them under the upper bound of 60 million tons. This kept the performance measure from being penalized for excessive feed grain carry-overs. Similarly, year ending carry-overs for cotton and wheat were reduced (about 40%) from their respective baseline values.

Prices for the three commodities increased from 10% for corn to 22% for wheat over the four-year period compared to the baseline (table 6). Livestock supply response to the higher corn prices resulted in higher cattle and hog prices during the latter years. By the final year, realized net farm income increased by 10% with a reduction in government payments of over 27%. Solution values for annual consumers' food expenditures were within their upper bounds, 101% of the baseline values, for all years except the last, which was 101.2% of the baseline.

The solution values for the loan rates in table 4 are robust, in that 10% changes in their values do not appreciably affect the final results. This, of course, may not be the case if the assumption concerning perfect knowledge is dropped. If crop yields and exports are stochastic, the solution values for loan rates may be higher. However, they also could be lower to reduce the possibility of a large positive supply response for the three crops leading to increased CCC stocks. The solution values for acreage diversion are not as robust as loan rates because of their direct impact on government payments and crop prices and their indirect impacts on livestock producers' incomes and consumers' food costs. Increasing the upper boundary constraints on wheat and cotton acreage diversion by 10% would cause only minor changes in the results.

Table 5. Control Solution Values for Output Variables in the Criterion Function with Designated Boundaries, and for Deficiency Payment Rates per Yield Unit, 1978–81

Item	1978	1979	1980	1981
Ending year stocks				
Feed grains (million tons)	59.9	59.9	60.3	60.1
Wheat (million bushels)	1,119.9	1,125.4	1,247.5	1,417.3
Cotton (million bales)	2.7	2.1	2.6	2.6
Consumers total expenditures for food ($ billions)	188.3	197.7	207.1	216.5
Total CCC storage and interest costs ($ millions)	150.0	17.0	0.0	0.0
Total government payments ($ millions)	3,180.0	3,460.0	3,680.0	4,266.0
Deficiency payments ($ millions)	736.5	371.1	782.4	1,416.9
Diversion payments ($ millions)	1,574.5	2,161.9	2,163.6	2,076.1
Other government payments ($ millions)	869.0	927.0	734.0	773.0
Deficiency payment rates				
Corn ($/bushel)	0.01	0.0	.08	.29
Wheat ($/bushel)	.49	.26	.34	.49
Cotton ($/pound)	0.0	0.0	0.0	0.0

Table 6. Index Number of Changes in Selected State Variables in Control Solution (Baseline Variable Values = 100.0)

Item	1978	1979	1980	1981	1978–81
Commodity prices					
Corn	104.5	110.5	113.0	113.5	110.4
Wheat	106.8	123.4	127.7	128.9	121.7
Cotton	112.9	118.2	117.3	114.5	115.7
Cattle and calves	100.0	102.2	104.1	104.0	103.2
Hogs	100.0	102.4	107.5	108.0	104.6
Ending year carryovers					
Feed grains	85.1	72.5	68.9	67.3	72.9
Wheat	72.8	61.6	60.0	60.0	62.5
Cotton	62.8	50.0	57.8	63.4	58.5
Realized net farm income	104.4	100.0	105.9	110.4	105.1
Total government payments	105.3	97.5	78.1	72.9	85.1
Deficiency payments	64.0	14.2	19.7	27.9	31.5
Consumers' food expenditures	100.0	100.1	101.0	101.2	100.7
Sum of consumers' food expenditures and government payments	100.1	100.4	100.5	99.6	100.4

Summary and Conclusions

One objective of this paper was to describe the process of commodity program administration in an adaptive control framework. The second objective was to illustrate the use of an adaptive control model for agricultural policy. Commodity program decision making can be viewed as a sequential, multiperiod control problem. Parameter learning and information updating take place through time in the actual decision process. When applying a control mechanism to a model of the real system, the parameter and information updates can be introduced by the investigator as they become available and the control problem can be resolved.

Use of this approach, coupled with a control algorithm used with the structural relationships, has some definite advantages. It permits control applications to policy problems in which numerous interdependent controls are available. Nonlinearities in modeled relationships can be preserved. An obvious disadvantage is that only (weak) passive learning is permitted. Because only point estimates of parameters are updated, the estimated solutions do not allow for parameter uncertainties.

The empirical portion of the paper presents a first-round application of the suggested sequential use of modeling-control techniques. The application demonstrates the feasibility of applying control procedures to a multicommodity agricultural policy simulator. They provide a means of simultaneously selecting control values in light of their short-term and longer-term effects on the modeled system.

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Distribution of Research Gains in Multistage Production Systems

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In a multistage production system, research that reduces production costs at one stage provides benefits to producers at all stages and to consumers. Agricultural production is assumed to involve three stages: nonfarm input, farm, and marketing. Research causes a parallel drop of the supply curve. Benefits are measured as changes in economic surplus. With a competitive model, the distribution of research benefits is the same for research directed at each production stage. Implications for the distribution of research benefits of some forms of imperfect competition are investigated.

Key words: economic surplus, multistage production, research benefits.

Modern agriculture involves a series of processes organized by different sets of decision makers. In this paper we consider three production stages in providing food products to consumers: an input supply sector providing off-farm inputs such as fertilizer, machinery, and fuel; a farm sector; and a marketing sector providing off-farm storage, transport, processing, and distribution. In practice, off-farm activities use more resources than farm activities. Of each U.S. consumer dollar spent on food, about two-thirds goes to the marketing stage and one-third to the farmer. In turn, about half of gross farm receipts are used to purchase off-farm inputs.

This paper evaluates the effects of research at one stage of the production chain on other production stages and on consumers. Recognizing limitations on available research resources, we should provide answers that are a useful input for allocation decisions for these resources among research projects. Our analysis estimates the aggregate benefits and their distribution from research that reduces production costs for input supply, farm, or marketing activities.

Our model extends the single-process, commodity-surplus model for evaluating research to allow multistage production. The single-process model is reviewed by Lindner and Jarrett (1978), with modifications suggested by Rose and by Lindner and Jarrett (1980). The effects of research at each of the three stages are specified as a downward shift in the supply curve for goods and services at that stage.[1] This supply shift has implications for prices and quantities at all stages of the system. Research benefits are measured as changes in economic surplus.[2] The research benefits refer to gross annual benefits. A complete analysis of the flow of benefits over time, variation in adoption rates, and research costs can be developed readily from the estimates in this paper (see Marsden et al.). This paper shows that farmers and consumers will benefit from research in the input supply and marketing production stages as well as in the farm stage. In fact, they may receive greater benefits from off-farm-oriented research than from farm-oriented research.

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[1] The research results could be technical and economic/organizational changes which reduce production costs per unit output or which increase production per unit input. No consideration is given to research which shifts final consumer demand or which changes final product quality.

[2] The changes in economic surplus are additional amounts consumers and producers would be prepared to pay to operate at the postinnovation market outcome rather than the preinnovation outcome. Willig establishes the argument for consumers. The issues are less clear for producers' quasi-rent. Mishan provides a general theoretical framework, and the interchange between Lindner and Jarrett (1978, 1980) and Rose applies specifically to the research problem. We regard the change in measured producer surplus as a rough estimate of the change in available rent for quasi-fixed resources.

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A Simplified Model

In this section we use graphs and algebra to evaluate and compare the effects of research that reduces farm production and marketing services costs. For simplicity we assume that the supply of nonfarm inputs and of marketing goods and services is perfectly elastic. These are reasonable approximations, given the absence of peculiar inputs for these industries, because they use a small proportion of the economy's resources and because there is scant evidence of long-run diseconomies of size. They are, however, relaxed in subsequent sections. For simplicity we assume linear supply and demand curves, a constant per unit margin between farm and retail prices, and competitive price behavior.

The situation is described in figure 1. Retail or final consumer demand is D_r. The constant per unit cost of providing marketing services is M. The derived demand curve for the farm product is $D_f = D_r - M$. A constant rate of transformation between farm and retail product is assumed. The farm product supply curve is S_f. With these assumptions, the initial quantity equilibrium is Q, retail price is P_r, and farm price is P_f.

Consider first technological change in the marketing stage. This is reflected as a reduction in the costs of providing storage, transport, processing, and distribution services, say, by w per unit. Thus the retail-farm margin falls to $M' = M - w$. In figure 1 the reduced margin leads to an upward shift of the farm product demand curve from $D_f = D_r - M$ to $D'_f = D_r - M'$. Quantity increases from Q to Q', farm price increases from P_f to P'_f, and retail price falls from P_r to P'_r. Under our assumptions of a perfectly elastic supply curve of marketing activities and competitive pricing, marketers continue to earn normal profits but on a larger turnover. With the retail price fall, consumer surplus increases by area $P'_rP_r G K$. The quasi-rent to fixed farm resources increases by $P_fP'_fD C$. The aggregate gain is S R D C. Algebraically, the gain for consumers, $G_c(m)$, gain for farmers, $G_f(m)$, and aggregate gain, $G(m)$, from reduced marketing costs can be represented as

$$(1)\quad G_c(m) = (P_r - P'_r)Q + \tfrac{1}{2}(P_r - P'_r)(Q' - Q) = \tfrac{1}{2}(P_r - P'_r)(Q + Q'),$$

$$(2)\quad G_f(m) = (P'_f - P_f)Q + \tfrac{1}{2}(P'_f - P_f)(Q' - Q) = \tfrac{1}{2}(P'_f - P_f)(Q + Q'), \text{ and}$$

$$(3)\quad G(m) = G_c(m) + G_f(m) = \tfrac{1}{2}\, w(Q' + Q).$$

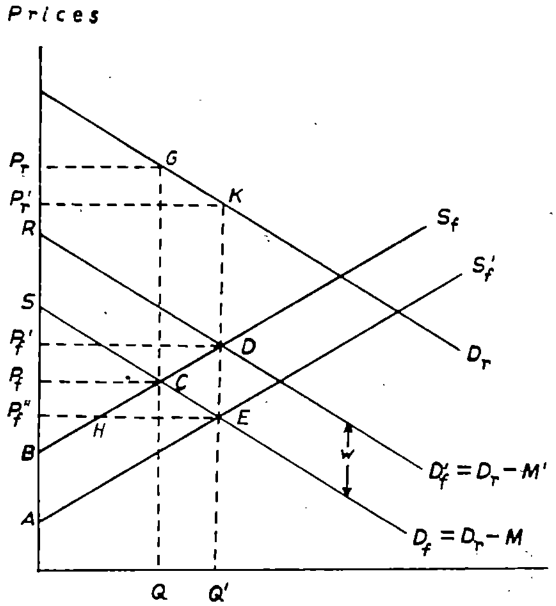

Figure 1. Quantity of farm output and of retail output (defined in terms of farm output)

Represent the retail demand equation by $D_r = a - \alpha P_r$, the farm supply equation by $S_f = b + \beta P_f$, and recall that $P_r = P_f + M$. Note that the elasticity of demand is $\alpha P_r/Q$, the elasticity of supply is $\beta P_f/Q$. After some algebra, the gains from a reduction in the marketing margin can be expressed as

$$(4)\quad G_c(m) = \beta Q w/(\alpha + \beta) + \alpha\beta^2 w^2/[2(\alpha + \beta)^2],$$

$$(5)\quad G_f(m) = \alpha Q w/(\alpha + \beta) + \alpha^2\beta w^2/[2(\alpha + \beta)^2], \text{ and}$$

$$(6)\quad G(m) = Qw + \alpha\beta w^2/[2(\alpha + \beta)].$$

Second, consider the effect of a reduction in farm production costs by, say, v per unit output. Following Rose, we assume a parallel shift of the farm supply curve.[3] In figure 1 the farm technology change shifts the farm supply down to S'_f. Quantity increases from Q to Q', retail price falls from P_r to $P'_{r'}$, and farm price falls from P_f to P''_f. As before, marketers earn normal profits on a larger output. The retail price fall increases consumer surplus by area $P'_r\ P_r\ G\ K$. Producer quasi-rent increases by area $A\ B\ H\ E$ less area $P''_f\ P_f\ C\ H$. These terms give an aggregate social gain of area $A\ B\ C\ E$. Algebraically, the gain for consumers, $G_c(f)$, gain for farmers, $G_f(f)$, and the aggregate gain, $G(f)$, from reduced farm production costs can be represented as

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[3] It is recognized that the assumption of a parallel shift is critical. In particular, it guarantees that producers do not lose from research. With a divergent shift, including a pivotal shift, it is possible for producers to lose economic surplus. A convergent shift enhances gains in producer surplus. If one has information suggesting a nonparallel shift, and clearly one should recognize Rose's arguments, then formulas reported in Rose should be used.

$$(7)\quad \begin{aligned} G_c(f) &= (P_r - P'_r)Q \\ &\quad + \tfrac{1}{2}(P_r - P'_r)(Q' - Q) \\ &= \tfrac{1}{2}(P_r - P'_r)(Q + Q'), \end{aligned}$$

$$(8)\quad \begin{aligned} G_f(f) &= vQ + \tfrac{1}{2}v(Q' - Q) \\ &\quad - (P_f - P''_f)Q \\ &\quad - \tfrac{1}{2}(P_f - P'_f)(Q' - Q) \\ &= \tfrac{1}{2}[v - (P_f - P''_f)] \\ &\quad (Q + Q'), \text{ and} \end{aligned}$$

$$(9)\quad \begin{aligned} G(f) &= G_c(f) + G_f(f) \\ &= \tfrac{1}{2}\, v\, (Q + Q'). \end{aligned}$$

If we represent the retail demand and farm supply equations by $D_r = a - \alpha P_r$ and $S_f = b + \beta P_f$, after some algebra these gains can be expressed as

$$(10)\quad \begin{aligned} G_c(f) &= \beta Q v/(\alpha + \beta) \\ &\quad + \alpha\beta^2 v^2/[2(\alpha + \beta)^2], \end{aligned}$$

$$(11)\quad \begin{aligned} G_f(f) &= \alpha Q v/(\alpha + \beta) \\ &\quad + \alpha^2\beta v^2/[2(\alpha + \beta)^2], \text{ and} \end{aligned}$$

$$(12)\quad G(f) = Qv + \alpha\beta v^2/[2(\alpha + \beta)].$$

These formulas tell several interesting stories about the gains from research. First, they are formally similar. In particular, a one-dollar reduction in marketing costs gives the exact pattern of benefits as does a one-dollar reduction in farm production costs. Second, both consumers and farmers gain from technological change; the marketers and input suppliers gain extra sales but, because of perfectly elastic supply curves, no extra surplus. The gain to consumers is greater than the gain to farmers if the slope of the farm supply curve (as measured by β) is greater than the slope of the demand curve (as measured by α) and vice versa. Third, aggregate gains are proportional to the cost reductions and the initial level of output. While the demand and supply elasticities have a significant effect on the distribution of gains, they have only a small effect on aggregate gains because, empirically, the second right-hand term of (6) and (12) is small relative to the first (Marsden et al.).

A General Competitive Model

While retaining the assumption of competitive behavior, the model developed here allows for a rising supply function for nonfarm inputs and for marketing services as well as for farm production. The reasons might include industry-specific resources and diseconomies of size.

Our model can be written as

$$(13)\quad Q = a_0 - a_1 P^r,$$

$$(14)\quad M = b_0 + b_1 Q,$$

$$(15)\quad P^r = P^f + M,$$

$$(16)\quad Q = c_0 + c_1(P^f - P^i), \text{ and}$$

$$(17)\quad P^i = d_0 + d_1 Q,$$

where Q denotes product quantity specified at farm level and farm level equivalents, P^r is retail price, P^f is farm price, M is the retail-farm price margin, and P^i denotes the cost of nonfarm inputs per unit farm output. Equation (13) is a conventional retail demand equation. The retail-farm price margin equation includes a fixed component and a component which varies with turnover.[4] Equation (16) is the farm supply function with the explanatory variable being a gross margin, $P^f - P^i$. For convenience, we assume constant input-output coefficients between nonfarm inputs and farm output.[5] A rising supply function for nonfarm inputs is described in (17). Equations (13) through (17) can be solved to determine equilibrium market prices at the retail, farm, and input-supply levels, P^r, P^f, and P^i, and the quantity Q.

Now introduce research that lowers production costs for the marketing, farm, and input-supply sectors. In each case we assume the research causes a parallel downward shift of the relevant supply curve. Specifically, suppose production costs per unit output fall by k_i for the input sector, k_f for the farmer, and k_m for the marketer. Then the marketer, farm, and input supply schedules become

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[4] Preliminary attempts to generalize the margin equation to allow for a percentage markup caused problems in measuring producer surplus. The percentage margin model, e.g., $M = b_0 + b_1 P^r$ with $b_1 > 0$ implies a downward-sloping margin supply curve since P^r is a declining function of Q.

[5] The constant input-output assumption is an important one which can be relaxed. It means that quantity at each production stage does not fall as a result of research. Some forms of technological change will require relaxation of the constant input-output assumption. One example is a new variety requiring less fertilizer. Relaxing the assumption will affect the results for earlier production stages but will leave the results for higher stages and consumers largely unaffected. For the lower stages the fall in the input-output ratio means a negative effect on demand, which partly or fully offsets the demand-increasing effect of lower prices. In the latter case, industry quantity and economic surplus actually may decrease.

$$(18)\quad M = b_0 - k_m + b_1Q,$$

$$(19)\quad Q = c_0 + c_1k_f + c_1(P^f - P^i), \text{ and}$$

$$(20)\quad P^i = d_0 - k_i + d_1Q,$$

where all terms are as defined above. The postinnovation model now comprises the retail demand equation (13), the margin cost equation (18), the price link equation (15), the farm supply equation (19), and the input cost equation (20). These equations can be solved to determine equilibrium prices and quantity. The postinnovation prices and quantity are denoted with an asterisk.

Each type of cost reduction causes an increased quantity. In fact, a one-dollar per unit output cost reduction at any of the three production stages will have an identical effect on quantity. Farm production research in the absence of other research reduces retail and farm prices and increases input price. Marketing sector research reduces retail price and increases the farm and input prices. Input research reduces prices at all three levels.

These price and quantity changes can be used to measure welfare effects of research. Denoting the changes in consumer, marketer, farmer, input supplier, and aggregate surpluses by G_c, G_m, G_f, G_i, and G, respectively, we obtain

$$(21)\quad G_c = \tfrac{1}{2}(P^r - P^{*r})(Q + Q^*),$$

$$(22)\quad G_m = \tfrac{1}{2}(k_m + M^* - M)(Q + Q^*),$$

$$(23)\quad G_f = \tfrac{1}{2}((k_f + P^i - P^{*i}) + P^{*f} - P^f)(Q + Q^*),$$

$$(24)\quad G_i = \tfrac{1}{2}(k_i + P^{*i} - P^i)(Q + Q^*), \text{ and}$$

$$(25)\quad G = G_c + G_m + G_f + G_i, = \tfrac{1}{2}(k_i + k_f + k_m)(Q + Q^*),$$

where all terms are defined above. The consumer gain is a straightforward measure of extra surplus caused by the fall in retail prices. The derivation of change in producers' quasi-rents is similar to that described for the farmer in figure 1 above. It has two components. First, there is the reduction in per unit production costs caused by the research-induced downward shift of the supply curve. This is reflected by the k terms. The change in the cost of nonfarm inputs also shifts the farm supply curve. Second, the output price change affects producers' quasi-rent. This is the second term in the first bracketed term of (22), (23), and (24). The aggregate surplus measure in (25) uses the price identity (15) to cancel terms.

After some tedious algebra (available from the authors), alternative expressions for the gains from research are

$$(26)\quad G_c = c_1G/H,$$

$$(27)\quad G_m = b_1a_1c_1G/H,$$

$$(28)\quad G_f = a_1G/H,$$

$$(29)\quad G_i = d_1a_1c_1G/H,$$

$$(30)\quad G = Qh + a_1c_1h^2/2H,$$

with

$$(31)\quad h = k_i + k_f + k_m, \text{ and}$$

$$(32)\quad H = (1 + a_1b_1)c_1 + (1 + c_1d_1)a_1,$$

where all terms are defined above.

Notice that the aggregate benefits are identical for a one-dollar per unit output reduction in costs whether at the input supply, farm, or marketing level. Second, the aggregate benefits are proportional to the cost reduction and the initial level of output. Third, in general the aggregate benefits are little affected by the various demand and supply price elasticities since they affect only the $Q^* - Q$ term. The larger the demand and supply elasticities, the greater will be the additional output. Fourth, a research advance in any sector will provide benefits, or at worst convey no costs, to those in the other sectors. In the extreme case where the relevant sector supply curve is perfectly elastic (i.e., $d_1 = 0$ or $c_1 = \infty$ or $b_1 = 0$), that sector will gain no additional economic surplus because the downward shift of the supply curve will be exactly offset by the downward shift of the price received. Fifth, where the supply curves for the input supply and marketing sectors are horizontal, the general model reduces to the special case described first. Sixth, the share of the benefits to any one sector will be greater the more inelastic the supply curve for its output relative to that for the other sectors. Seventh, the distribution of the benefits between final consumers and all production sectors will favor consumers the more inelastic retail demand is relative to the various supply elasticities. Eighth, the ratio of consumer to farmer benefits depends only on the ratio of the price slopes of the retail demand and farm supply curves and is not affected by the slopes of the input supply and marketing services supply curves. Ninth, a one-dollar per unit cost reduction in terms of farm quantity at any of the three production stages has exactly the same effect on returns to consumers, marketers, farmers, and input suppliers.

Distribution of Research Costs

The distribution of the costs of a per unit output levy to finance research can be assessed with the research benefits model. A research levy, like any other variable cost, increases per unit output costs and can be represented as an upward shift of the supply curve of the sector paying the levy. The supply curve shift will induce changes in prices in the other sectors. The costs of research, represented as an upward supply curve shift, will be distributed in exactly the same way as the benefits of research, represented as a downward supply curve shift. Assuming validity of the general competitive model described above, formulas (26) through (32) can be used to evaluate the distribution of the costs of a research levy where the terms k_i, k_f, and k_m in (31) are interpreted as per unit output levies at the input supply, farm, and marketer stages of the agricultural system, respectively.

Since the benefits and the costs of research incurred at one stage are distributed identically between the different production stages and consumers, the argument for government intervention in research funding because some of the benefits from research at one stage go to other stages is not warranted. For example, a one-dollar per unit reduction in farm production costs because of research provides the same benefit to consumers as does the cost imposed by the market system on consumers of a one-dollar per unit levy on farm output to finance the research.

A different but related issue is the need for some form of government intervention to coordinate research funding at different stages of the production system. Because of the effects of the public good nature of research output, of uncertainty, and of size economies, sometimes it is argued that the private sector will invest less than the social optimum amount of funds in research. It is likely that these effects will be more important at the farm stage because of its atomistic structure and because of difficulties of patenting much of the research. By contrast, there is a higher degree of concentration in the input supply and marketer stages and many forms of technology are patentable. The previous discussion on the distribution of the benefits and costs of research suggest that government intervention should be directed not at providing funds for research but rather at establishing institutional arrangements to internalize externalities within each stage of the production process.

An important underlying assumption of this section is that there are no external benefits or costs of research in one commodity flowing over to other commodities. It is not difficult to think of cases where this assumption is unrealistic.

Imperfect Competition

While it is reasonable to treat consumers and farmers as perfect competitors, there are grounds for challenging the assumption for the input supply and marketing sectors.[6] For this paper, the key consideration is not the absolute level of prices but the extent to which technology-induced, production-cost changes are passed on in lower output prices. Here we compare the previous results with outcomes for a monopoly and for some administered markup rules.

Consider a monopolist in either the marketing or the input supply sector. For convenience assume that marginal costs are constant at K per unit and that the product demand curve can be represented by a linear function $P = a - bQ$, where P is price and Q is quantity. The monopolist will set price at $P_m = (a + K)/2$, whereas the perfectly competitive price is $P_c = K$, with $P_m > P_c$. Now suppose new technology reduces marginal cost by k per unit. Then the new price in the competitive industry will fall to $P^*_c = K - k = P_c - k$. The monopolist will reduce price to $P^*_m = (a + K$

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[6] For a discussion see, for example, Breimyer, Parker and Connor, and Barber. There seems to be a consensus that the main forms of competition are not the extremes of perfect competition or monopoly but rather imperfect competition and oligopoly. There is no unambiguous and generally accepted price formation model for either of these.

$- k)/2 = P_m - k/2$. That is, the monopolist will pass on half of the cost reduction. A rising marginal cost curve will mean that less than half of the cost reduction will be passed on. In general, a profit-maximizing monopolist will pass on some but not all of the cost decrease.

In imperfectly competitive industries, many price markup rules are found. A common procedure is to set output price P at some percentage above direct or variable costs C, giving $P = (1 + r)C$ where r gives the proportionate markup over direct costs to cover fixed costs and profits. If technology reduces fixed costs, it may take some time before the markup factor is reduced. If technology reduces direct costs, then strict application of the markup rule would result in output price falling by more than the cost reduction.

Despite the existence of imperfect competition in the real world, we favor the competitive model as a reasonable way to assess the effects of technological change. In general the agriculture industries are not highly concentrated (for national U.S. estimate, see Carter and Johnston; for some local estimates, see Marion et al.). Profits are low in comparison to most other manufacturing industries. For most agricultural industries, it seems unlikely that prices are more than 5% above competitive levels (see Marion et al.). Moreover, studies of the marketing margin, for example by George and King, indicate that for many products a large part of farm price changes is passed on to retail within a quarter. For these reasons, the competitive model may be a reasonable approximation, particularly over the longer term.

An Application

This section provides an illustrative application of the competitive model for the U.S. hog industry. Specifically, we consider the effects of a 10% reduction in the cost of nonfarm inputs, e.g., chemicals and machinery; in the cost of farm production, e.g., greater labor efficiency; and in the cost of marketing activities, e.g., increased efficiency in slaughtering and retailing. Aggregate benefits and their distribution between final consumers, pork wholesalers and retailers, hog farmers, and nonfarm input suppliers are assessed for alternative assumptions concerning supply price elasticities.

Values for the key variables required to apply the formulas are listed in table 1. They refer to average 1978 conditions. The quantity variable refers to the retail level and the prices are expressed in terms of retail product equivalent using USDA conversion ratios. In 1978 the gross farm value of hog production was just over $10 billion. Although estimates of the pork demand and farm hog supply price elasticities are available, no estimates were found for the marketing and input supply elasticities. Most available evidence points to a highly elastic long-run supply curve. For illustrative purposes we consider elasticities of 2.0 and ∞ and, hence, price flexibilities of 0.5 and 0. To transform the elasticities (flexibilities) to slopes, we multiplied by the appropriate quantity-to-price ratio. The cost-reducing effects of technological change are arbitrarily set at 10% of value added for each production stage. For example, the reduction in marketing costs, k_m, is determined as $k_m = 0.1\ M = 0.1\ (P^r - P^f) = \$0.067$. In practice, values for the cost-reduction terms would come from consultation with researchers, research administrators, and others involved in proposed or ongoing research activities.

Some estimates of the distribution of the benefits of cost-reducing technology are reported in table 2. The results illustrate the conclusions drawn from the theory. The aggregate gain, expressed as economic surplus, from any particular cost reduction is insensitive to assumptions about supply elasticities. In this particular example, the price slope of the farm level pork supply equation, c_1, is nearly double that of the retail level demand, a_1. For this reason, consumer benefits in each situation are nearly double farm benefits. The estimates illustrate that the benefits to any particular sector do not depend on where the cost reduction occurs as long as it provides the same dollar saving per unit of farm equivalent output. Since marketing costs are the largest cost component of a pound of pork purchased by the consumer, a 10% reduction in marketing costs (6.7¢ per pound in our example) provides greater benefits in aggregate and to each sector than a 10% reduction in costs in the other sectors.

Conclusions

The key message of this paper is that in a multistage production system, research-induced cost reductions in one part of the sys-

Table 1. Values of Variables for U.S. Hog Industry

Variable	Value	Description
Q	13,209 million pounds	Commercial hog production (carcass weight)[a]
P^r	\$1.436/pound	Retail price of pork[a]
P^f	\$0.766/pound	Net farm value of pork[a]
P^i	\$0.150/pound	Value of nonfarm inputs[b]
e_d	−0.8	Retail elasticity of demand for pork[c]
e_f	0.7	Farm supply elasticity for hogs[d]
e_m	2 or ∞	Elasticity of supply of marketing services[e]
e_i	2 or ∞	Elasticity of supply of nonfarm inputs[e]
k_i	\$0.015/pound	Cost-reducing technological change arbitrarily set at 10% of value added
k_f	\$0.062/pound	
k_m	\$0.067/pound	

[a] From USDA (1981).

[b] From USDA (1980) using nonfarm inputs as 20% of farm value.

[c] Average figure from George and King, Arzac and Wilkinson, and Freebairn and Rausser.

[d] Average figure from Dean and Heady and Freebairn and Rausser.

[e] See text.

tem provide benefits to consumers and all other members of the production system. Under the special assumptions of competitive behavior, linear supply and demand curves, and constant input-output coefficients for the product as it moves through the system production chain, we have shown that the distribution of the research benefits is the same whether the cost reductions occur at either the nonfarm input, farm, or marketing sectors. The relative distribution between sectors depends on the elasticity of retail demand and the supply elasticities of value added at each stage of the production chain. In general, the more inelastic a sector's supply is relative to that of other sectors, the greater will be the share of research gains going to that sector. The aggregate gain was affected little by changes in the various price elasticities.

These results are modified, but not overturned, when the perfect competition assumption is relaxed. Monopolistic behavior will increase the share going to the innovating sector. With a pure monopoly model, about half of the cost reduction is passed on in lower prices to other sectors. Because of uncertainty

Table 2. Estimated Returns from Research from Different Types of Technical Change in the U.S. Hog Industry for Different Assumptions (\$ Million)

	Recipients of Benefits[b]				
Industry Situation[a]	Input Supply	Farmer	Marketer	Consumer	Aggregate
1. Perfectly elastic input and marketer supply ($e_i = e_m = \infty$)					
(i) $k_i = 0.015$	0	65	0	134	199
(ii) $k_f = 0.052$	0	272	0	556	828
(iii) $k_m = 0.067$	0	295	0	601	896
2. Less than perfectly elastic input supply ($e_i = 2$, $e_m = \infty$)					
(i) $k_i = 0.015$	5	64	0	130	199
(ii) $k_f = 0.052$	23	265	0	540	828
(iii) $k_m = 0.067$	24	287	0	585	896
3. Less than perfectly elastic marketing supply ($e_m = 2$, $e_i = \infty$)					
(i) $k_i = 0.015$	0	58	22	119	199
(ii) $k_f = 0.052$	0	242	92	493	827
(iii) $k_m = 0.067$	0	262	100	533	895
4. Less than perfectly elastic input and marketing supply ($e_i = e_m = 2$)					
(i) $k_i = 0.015$	5	57	22	115	199
(ii) $k_f = 0.052$	20	236	90	481	827
(iii) $k_m = 0.067$	22	255	97	521	895

[a] All other variables as specified in table 1, and k's are zero unless specified otherwise.

[b] Based on formulas (26) to (32) in text.

about price formation in imperfectly competitive industries, it was not possible to be definite about this case. Even so, we hypothesize that, in the long run, a high proportion of research-induced cost reductions are passed on. That is, we argue that the competitive model offers a reasonable approximation.

There is little reason to argue that research opportunities are greater or research costs are less at the farm level than at the marketing and input levels. It seems, therefore, that the choice of agricultural research projects should recognize opportunities at all levels in the system. This is particularly true when we recognize the size of the input and marketing components in the final cost of food purchased by consumers.

Finally, while the paper has reported precise formulas, they should be used as guidelines only. They are based on simplifying assumptions which provide reasonable approximations. Application of the formulas requires data on current prices and quantity, the relevant price elasticities of supply and demand, and the extent of research-induced cost reductions. In reality, we may have only rough estimates of some of these variables.

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Optimal Expenditures for Agricultural Research and Extension: Implications of Underfunding

Fred C. White and Joseph Havlicek, Jr.

Significant increases in agricultural productivity will be needed for the United States to meet its future food policy goals related to an abundant and stable food supply. The nation's ability to meet this challenge will depend on the level of investment in agricultural research and extension. Each dollar of underfunding relative to the economically efficient level of research and extension expenditures (*a*) will cost the government \$2.56 (\$1.50 discounted) if it later makes up for the low investment level or (*b*) will cost consumers \$4.39 (\$3.07 discounted) if the government does not make up for the low level of investment.

Key words: agricultural extension, agricultural research, optimal control, productivity.

Increases in agricultural productivity are often attributed to production-oriented agricultural research and extension. Because such activities use resources, an important question is whether or not it pays for society to invest in them. Many studies indicate high returns to a wide range of agricultural research and extension investments (for a summary of these results, see Peterson and Hayami; and Arndt, Dalrymple, Ruttan). However, we still need to assess the long-run consequences of alternative levels of agricultural research and extension investment. Investment could be adjusted to achieve desired levels of future agricultural prices relative to other goods and services. Because of the lagged response to agricultural research, it obviously would be impossible to control short-run fluctuations in prices through research and extension investment. However, long-run price trends might be controlled by adjusting such investments.

This paper analyzes the investment patterns for agricultural research and extension that will achieve selected levels of expected growth in agricultural output.[1] More specifically, the paper will (*a*) formulate an economic model of the agricultural sector in which technological change is achieved from investment in agricultural research and extension, (*b*) identify optimum patterns of investment based on rate of return estimates, and (*c*) assess the consequences of failure to achieve the optimum investment.

Conceptual Framework

Economic policies generally are formulated under uncertainty about the eventual levels of important uncontrollable factors. By anticipating these variables, policy makers can successfully achieve selected economic objectives. Hence, economic policies may be viewed as the use of available instruments to achieve desired values and time paths of policy targets (Fox, Sengupta, Thorbecke).

The objective of the policy maker may be to change the price trend of agricultural commodities relative to other goods and services. The problem is to select the investment level of agricultural research and extension so that the target variable, the desired price $\tilde{P}_t$, is attained. In general, farm price is an important variable because higher farm prices are translated into higher food prices. Rising food prices can increase the cost of living. Also, farm prices are a major determinant of farm

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[1] Although future outcomes cannot be controlled exactly, it is possible to control the expectation of certain outcomes.

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sectoral income. If the rate of growth in agricultural productivity is too rapid relative to demand growth, farm prices and farm income may become depressed. Severe adjustment burdens may be imposed on marginal resources in the sector.

Research and extension expenditures affect agricultural supply through their impact on agricultural productivity. An increase in these expenditures would be expected to increase productivity in subsequent years and, hence, shift the supply curve to the right at all prices. This results in a decline in the market price of agricultural output, *ceteris paribus*. Assume that policy makers can identify some long-run desired levels of the target variable $\bar{P}_t$. Their objective is to control the economic system by adjusting research and extension expenditures to keep the target variable as close as possible to the desired level. Performance of the system can be judged by deviations of actual price P_t from its desired level $\bar{P}_t$. Previous studies on price instability have assumed that the cost of deviation from the desired price level can be adequately measured by a quadratic cost function (Turnovsky). This is represented by

$$J = \sum_{t=1}^{T} (P_t - \bar{P}_t)^2. \tag{1}$$

The problem is to find the time path of the control variable, research and extension expenditures $R_t (t = 1, \ldots, T)$, that will minimize the welfare loss from being away from the desired price level.

In addition, there may be costs associated with instability in the policy instrument. Holbrook (p. 57) argues that this occurs when it is necessary for the policy maker continually to make greater changes in the policy instrument to offset effects of past policies. Assume that the policy maker visualizes long-run desired values for the policy instrument, $(\bar{R}_t)$, based on some trend. In this case, instruments have costs, so the total cost function must be expanded:

$$J = \sum_{t=1}^{T} v(P_t - \bar{P}_t)^2 + \sum_{t=1}^{T} w(R_t - \bar{R}_t)^2. \tag{2}$$

The policy maker attributes costs v and w to the target and instrument variables, respectively. These costs can be identified directly by interviewing policy makers or indirectly by observing effects of past decisions. The latter approach will be used in the present study.

Research and extension expenditures in each period will affect productivity and, hence, prices many years later. This complicates the decision process. Because of the dynamic nature of this problem, the choice of research and extension expenditures in one period restricts the possibilities in later periods. Therefore, the multiperiod character of the problem must be considered in choosing the expenditures for each period.

The Model

Estimation of market equilibrium through time depends on specification of supply and demand schedules. Since investments in research and extension are long-run supply phenomena, simple models using short-run supply and demand elasticities would be inappropriate. The supply and demand relationships must be sufficiently flexible to model the system through time. It is assumed here that both quantity demanded and quantity supplied are functions of current and past prices formed as a Koyck distributed lag. These relationships account for short-term and long-term adjustments in quantities demanded and supplied to price changes. These supply and demand relationships are similar to Yeh's and are as follows:

$$Q_{dt} = \alpha_d P_t^{\lambda^0 \beta_d} P_{t-1}^{\lambda^1 \beta_d} \ldots P_{t-\infty}^{\lambda^\infty \beta_d} \exp\left[\sum_{i=t_0}^{t} g_{di}\right], \text{ and} \tag{3}$$

$$Q_{st} = \alpha_s \left(\frac{P}{PP}\right)_t^{\mu^0 \beta_s} \left(\frac{P}{PP}\right)_{t-1}^{\mu^1 \beta_s} \ldots \left(\frac{P}{PP}\right)_{t-\infty}^{\mu^\infty \beta_s} \exp\left[\sum_{i=t_0}^{t} g_{si}\right], \tag{4}$$

where Q_d and Q_s are quantities demanded and supplied, respectively; P and PP are prices received and paid by farmers, respectively; g_d and g_s are rates of shift in demand and supply, respectively; β_d and β_s are short-run price elasticities of demand and supply, respectively; λ and μ are weights related to speed of adjustment; and α_d and α_s are constants.

Shifts in the demand for agricultural output, g_d, can arise from changes in population, per capita disposable income, and exports. Likewise, shifts in the supply schedule, g_s, may result from changes in such factors as prices of inputs and productivity of inputs as related to research expenditures, education of farmers, and weather.

Equilibrium in the present model can be found by equating supply and demand:

$$(5) \qquad Q_{dt} = Q_{st}.$$

By introducing lagged values for quantity demanded and quantity supplied relationships in equations (3) and (4), it is possible to derive reduced-form equations of the distributed lagged models. Substituting the reduced-form equations into equation (5), equilibrium price can be found from the expression

$$(6) \quad P_t^{(\beta_d - \beta_s)} = \alpha_t Q_{t-1}^{(\mu-\lambda)} \exp\left[(1-\mu)\sum_{i=t_0}^{t-1} g_{si} + g_{st}\right],$$

where

$$\alpha_t = \alpha_d^{(\lambda-1)} \alpha_s^{(1-\mu)} PP^{-\beta_s} \exp\left[(\lambda-1)\sum_{i=t_0}^{t-1} g_{di} - g_{dt}\right].$$

Most variables affecting the constants in the supply and demand equation can be determined outside the model and do not affect the formal optimal control problem. However, input productivity related to research expenditures is of special interest in this study. Agricultural productivity is hypothesized to have a lagged response to research and extension investment. This relationship can be characterized as follows:

$$(7) \qquad PI_t = \alpha_{pt} \prod_{j=1}^{n} R_{t-j+1}^{\gamma_j},$$

where PI_t is the productivity index, output per unit of input; R_{t-j+1} is aggregate research and extension expenditures in time period $t-j+1$; γ_j is the coefficient associated with the aggregate research and extension expenditure in time period $t-j+1$; and α_{pt} is a conglomeration of the effects of other supply shifters.

Changes in agricultural productivity affect the supply equation through the g_{st} term. This supply shifter can be defined as

$$(8) \qquad \exp(g_{st}) = PI_t / PI_{t-1}.$$

This term represents the annual percentage of increase in productivity. Equation (4) implies that a 1% increase in productivity increases the quantity supplied at each price by 1%.

Price, P_t, is the state variable and research expenditure; R_t, is a control variable. The problem is to control research expenditures in each year so that the future time paths of P_t will closely follow a designated time path.

The effect of research expenditures on equilibrium price can be determined by substituting equation (7) into equation (8):

$$(9) \quad g_{st} = (\alpha'_{pt} - \alpha'_{pt-1}) + \sum_{j=1}^{n+1} (\gamma_j - \gamma_{j-1}) R'_{t-j+1},$$

where γ_j is 0 for $j = 0$ and $n + 1$.

The prime (′) on the variables indicates natural logarithms. Further substituting this result into equation (6), taking natural logarithms, and simplifying the expression yields:

$$(10) \quad P'_t = \left[\hat{\alpha}_t + (\mu - \lambda) Q'_{t-1} + (1-\mu) \sum_{i=t_0}^{t-1} \sum_{j=1}^{n+1} (\gamma_j - \gamma_{j-1}) R'_{i-j+1} + \sum_{j=1}^{n+1} (\gamma_j - \gamma_{j-1}) R'_{t-j+1}\right] / (\beta_d - \beta_s),$$

where

$$\hat{\alpha}_t = \alpha'_t + \alpha'_{pt} - \alpha'_{pt-1} + (1-\mu) \sum_{i=t_0}^{t-1} (\alpha'_{pi} - \alpha'_{pi-1}).$$

The equation of motion is obtained from equation (10) for period $t + 1$ by subtracting P'_t from both sides. This difference equation is

$$(11) \quad \Delta P'_t = \left[(\hat{\alpha}_{t+1} + (\mu - \lambda) Q'_t + (1-\mu) \sum_{i=t_0}^{t} \sum_{j=1}^{n+1} (\gamma_j - \gamma_{j-1}) R'_{i-j+2} + \sum_{j=1}^{n+1} (\gamma_j - \gamma_{j-1}) R'_{t-j+2}) / (\beta_d - \beta_s)\right] - P'_t.$$

This is the equation of motion for $t = 0, 1, \ldots, T - 1$.

The objective function to be minimized is

$$(12) \quad J = \sum_{t=1}^{T} (P'_t - \bar{P}'_t)^2 + \sum_{t=1}^{T} w(R'_t - rR'_{t-1})^2,$$

where $\bar{P}'_t$ is the planned target value for price, w is the weight on variability in research expenditures, and r is a factor reflecting growth in research expenditures. Inclusion of the last term reduces variability in the instrument. The weight w indicates the importance of research expenditure stability relative to achieving target values for price. The problem is to minimize (12) subject to (11).

This problem can be solved in numerous ways. It is possible to form a Hamiltonian from equations (11) and (12) and then take derivatives to determine the canonical equations or necessary conditions for an optimal solution (Chow, pp. 157–60). Alternatively, the problem can be cast in a quadratic programming framework in which equation (12) is minimized with respect to equation (11) for any desired length of time. Both approaches were used here to verify the results. However, the quadratic programming approach is the easiest to use.

Supply and Demand Parameters

The price elasticities used in this analysis were based on previous econometric studies of U.S. agricultural production. Aggregate short-run demand elasticity was based on previous estimates of domestic and foreign demand elasticities. There has been general agreement that the elasticity of demand for farm output at the retail level in the domestic market is approximately −0.25 (Waugh; Bucholz, Judge, West; George and King). Price elasticity of demand at the farm level is assumed to be −0.15 (Yeh). Foreign demand elasticities are based on "restricted trade maximum" estimates of Bredahl, Meyers, and Collins, which they consider to be the most realistic of their estimates. They are used to calculate an overall foreign demand elasticity based on average exports of the commodities they considered.[2] Weighting domestic and foreign demand elasticities on the basis of the relative importance of the two markets resulted in a farm-level value of −0.25 for the short-run demand elasticity. The short-run elasticity of supply for total farm output is expected to be quite low, because resource adjustment between farm and nonfarm commodities is limited. Studies by Griliches (1959, 1960), Heady and Tweeten, and Tweeten and Quance report the short-run elasticity of supply to be near 0.20. This is the estimate used in this study. Yeh's estimates for the lagged parameters, 0.3 for λ in the demand equation and 0.8 for μ in the supply equation, are used in this study.

Determinants of Productivity Growth

Growth in agricultural productivity, defined as an index, can be represented by an increase in output per unit of input. Increases in productivity reflect changes in the quality of inputs, but such changes generally are not captured in the total input measure. These changes can be attributed to an increase in knowledge resulting from education, research, and extension. The relationship between input quality improvements and research, extension, and education may be measured by inserting these variables directly into the production function. Griliches (1964) was the first to use education, research, and extension as separate variables in production functions. Since then several others also have used this approach (Peterson and Hayami).

Extension's role is distinct from that of research. Therefore, a separate extension variable should be used in the production function. However, measuring the separate influence of extension on agricultural productivity has been difficult because of the high multicolinearity between these variables in time-series data. Even sophisticated econometric techniques such as ridge regression cannot overcome this problem. Therefore, research and extension expenditures are combined into one variable in this analysis. Following Evenson (1967), it was assumed that research and extension expenditures in one year may affect productivity over several years.

The model used to explain changes in productivity over time is similar to that in Lu, Cline, and Quance and is

$$(13) \quad PI_t = \prod_{j=1}^{n} R_{t-i+1}{}^{\gamma_j} E_t{}^{\beta_1} \exp\,(\beta_2 W_t),$$

where PI_t is the value of the aggregate productivity index for U.S. agriculture in year t, R_{t-i+1} is the lagged values of production-oriented research and extension expenditures, E_t is the educational attainment of farmers in year t, W_t is the weather index in year t, and n is the length of lag. Two factors are of particular interest: (*a*) the mean length of the lag and (*b*) the effect of research and extension on productivity.

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[2] The export demand elasticities of Bredahl, Meyers, and Collins are corn, −1.31; sorghum, −2.36; wheat, −1.67; soybeans, −.47; and cotton, −.65. These estimates were weighted by the 1974–76 export value percentage importance of these commodities: corn, .3052; sorghum, .0469; wheat, .3445; soybeans, .2259; and cotton, .0774. (Export values were from *Agricultural Statistics, 1978*). The resulting short-run foreign demand elasticity is −.847.

Productivity Model Estimation

The contribution of research and extension to aggregate U.S. agricultural productivity was estimated for the period 1943–77. With the hypothesized lag structure on research and extension expenditures, the expenditure data covered the period 1929–77. Production-oriented expenditures for such federal agencies as the Agricultural Research Service, Economic Research Service, and Soil Conservation Service were obtained from the annual *Combined Statement of Receipts, Expenditures, and Balances of the United States Government* and the *Budget of the United States Government,* which contains a functional breakdown of appropriations by activity. Unpublished data were obtained from the Cooperative Extension Service for extension expenditures and from the Cooperative State Research Service for the state agricultural experiment stations' expenditures. A detailed description of the sources of research and extension expenditures is presented in Cline. The productivity index is from *Changes in Farm Production and Efficiency* (U.S. Department of Agriculture). The education index reported in Evenson (1968) and the weather index reported in Stallings and Kost were updated for this study. The educational attainment index considers years of schooling completed for farmers, farm managers, farm laborers, and foremen, as well as income-schooling factors. The weather index reflects short-term deviations in crop yields from long-term trends. A weather index of 100 is equal to the long-term trend and indicates normal weather.

The model in equation (13) was estimated using the Almon distributed lag procedure (Almon). As expected, the error terms were serially correlated initially. To overcome this problem, all variables were adjusted with a first-order autoregressive scheme (e.g., $X_t - \rho X_{t-1}$). Following Cline, a second-degree polynomial was selected as most appropriate. Varying lengths of lags were investigated, and the appropriate one was determined using Theil's minimum standard error criterion.

After comparing regression results for several lag lengths, the fourteen-year lag (the current year and the previous thirteen years) was selected. These regression results, which show the contribution of research and extension to agricultural productivity, are shown in table 1. The high coefficient of determination (R^2) indicates that the model did a good job explaining the variation in the agricultural productivity index. The Durbin-Watson statistic of 2.3 suggests no serial correlation in the final model.

The regression results, which are consistent with Evenson's findings (1967), indicate that research and extension expenditures in year t will have their greatest contribution to agricultural productivity in the sixth and seventh year. In fact, the impact of these expenditures in each of these years is four times as great as their impact in the first year. The sum of the regression coefficients of the research and extension variable is 0.0381 indicating that, over its lifetime, a 1% increase in research and extension expenditures increases aggregate productivity by 0.0381%. The individual coefficients show the distribution of this impact over time. The two other explanatory

Table 1. The Contribution of Research and Extension Expenditures to Aggregate U.S. Agricultural Productivity, 1943–77

Explanatory Variables	Regression Coefficients
$\ln E_t - \rho \ln E_{t-1}$	.77209
	(3.784)[a]
$W_t - \rho W_{t-1}$	.00216
	(5.581)
$\ln R_t - \rho \ln R_{t-1}$	.00095[b]
$\ln R_{t-1} - \rho \ln R_{t-2}$	.00176
$\ln R_{t-2} - \rho \ln R_{t-3}$	.00245
$\ln R_{t-3} - \rho \ln R_{t-4}$	.00299
$\ln R_{t-4} - \rho \ln R_{t-5}$	.00340
$\ln R_{t-5} - \rho \ln R_{t-6}$	.00367
$\ln R_{t-6} - \rho \ln R_{t-7}$	.00381
$\ln R_{t-7} - \rho \ln R_{t-8}$	.00381
$\ln R_{t-8} - \rho \ln R_{t-9}$	.00367
$\ln R_{t-8} - \rho \ln R_{t-10}$	.00340
$\ln R_{t-10} - \rho \ln R_{t-11}$	.00299
$\ln R_{t-11} - \rho \ln R_{t-12}$	.00245
$\ln R_{t-12} - \rho \ln R_{t-13}$	.00176
$\ln R_{t-13} - \rho \ln R_{t-14}$	.00095
ρ	.856
R^2	.988

[a] Student *t*-values are reported in parentheses.

[b] A joint *F*-test of the null hypothesis that all the regression coefficients for the *R*'s are equal to zero was rejected at the 1% level of significance.

variables—education and weather—also have statistically significant effects (.01 level) on agricultural productivity.

Empirical Analysis for 1981–90

Equilibrium supply and demand conditions were analyzed under a situation of moderate growth in demand (1.6% compounded annually) over the period 1981–90.[3] From the supply side of the model, productivity is determined endogenously as a function of farmers' education and research and extension expenditures. Weather conditions are assumed to be average. The model allows for an annual growth rate in research and extension expenditures of 3%, similar to the 1929 to 1980 growth rate. Consequently, variations in these expenditures will be measured along a line having a growth trend. Finally, the weight w of expenditure instability is specified to be one-tenth the weight of instability in the target variable, farm price.[4]

Two main questions are considered: (*a*) what is the optimum pattern of agricultural research and extension expenditures; and (*b*) what are the consequences of failing to achieve the optimum pattern of expenditures? In analyzing the optimum pattern, selected target values of the farm price variable are related to rates of return on investment.

Rate of Return on Investment

The objective function in equation (12) was minimized with respect to the equation of motion (11) for a wide range of annual growth rates in farm prices. The equilibrium quantities obtained were used to calculate the marginal product of research and extension investment. Using the regression coefficients from the productivity index equation, the internal rate of return can be calculated as

$$(14) \qquad \sum_{j=1}^{n} \frac{\gamma_j(\overline{TQ}/\overline{TR})}{(1+IRR)^j} = 1,$$

where γ_j is the regression coefficient as previously defined, $\overline{TQ}$ is the geometric mean for agricultural output for the period 1981–90, $\overline{TR}$ is the geometric mean for research and extension expenditures for the period 1981–90, and IRR is the internal rate of return. The rate of return calculated in this manner was reduced by one-third to account for the impact of private research. The procedure is based on the assumption that the three categories—private research, public research, and extension—are equal in weight.

Table 2. Costs and Returns of Restricting Rising Agricultural Output Prices through Increased Research and Extension Expenditures, 1981–90

Annual Trend in Farm Price	Annual Research and Extension Expenditures	Rate of Return on Research and Extension Expenditures[a]
(%)	($ million)	(%)
0.7	695.8	36.0
0.6	968.1	27.9
0.5	1,348.2	21.2
0.4	1,878.4	15.6
0.3	2,618.0	10.9
0.2	3,649.4	6.9

[a] Rate of return on research and extension expenditures by the public sector after accounting for private research expenditures. Each of these three categories are assumed to be equal in weight.

The levels of research and extension expenditures required to achieve selected growth rates in real farm prices are reported in table 2, as well as the rate of return on those particular levels of expenditures. The rate of return declines as research and extension expenditures are used to reduce the annual growth rate in farm prices. For example, increasing annual expenditures for the 1981–90 period from $1,878.4 million to $2,618.0 million will reduce the annual growth rate in real farm prices from 0.4% to 0.3%. However, the rate of return on research and extension expenditures, shown in the third column of table 2, would drop from 15.6% to 10.9%. Other tabular figures may be interpreted similarly.

The research and extension expenditure pattern chosen as the base situation is that which would result in a 0.4% annual increase in real farm prices. This situation was chosen for further analysis because it is closest to the actual trend in research and extension expenditures. Furthermore, the 15.6% rate of return from this pattern of expenditures corresponds to the level that Ruttan (p. 531) argues are in the public interest. Agricultural quantity, price, and productivity indexes for the base pattern of research and extension expenditures are shown in table 3. In 1980 dollars, the base expenditure level is $1,621 million in 1981 and grows 3% annually through 1990. Total expenditures for the ten-year period are $18,472 million (or $13,408 million discounted, assuming a 6% discount rate). The indexes of farm production and prices received by farmers are equilibrium values simultaneously determined with the optimal pattern of research and extension expenditures. Farm production would be expected to increase 14.2% over the period, while real farm prices—the target variable—would increase approximately 2.7%. The productivity index is the ratio of output per unit of input for aggregate agricultural production. All three indexes are expressed on a 1967 = 100 basis.

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[3] The base scenario assumes a series E population (0.85% annual growth rate), 3% annual growth rate for per capita disposable personal income, and moderate growth in farm exports which reflects trends established prior to 1972.

[4] The coefficient of variation as measured by actual deviations from the trend from 1943–77 for real research and extension expenditures was only a fraction of that for real farm prices. This calculation and the relative importance of farm price in the present model led to our weighting deviations in farm price more heavily than deviations in research and extension expenditures.

Effects of Underfunding

Policy makers may be tempted to underfund agricultural research at less than optimum levels in order to cut current government spending. However, there may be long-run costs associated with such a strategy. Considering federal budgets for several years in the future allows a variety of approaches to be evaluated. Some selected approaches to reducing research and extension expenditures will be described and analyzed in this section. First, research and extension expenditures could be cut in the early years and then made up later, so that advances in productivity could continue leaving consumers no worse off. We hypothesize that this approach would require more government funding over the period but leave consumers virtually unaffected. Under a second approach, policy makers could cut support in the early years and then return expenditures to the base situation in later years. Finally, a new lower expenditure base could be established. The latter two approaches would result in a direct government saving but might substantially increase costs to consumers. An important question is whether or not the reduction in government expenditures ultimately would be offset by higher food costs.

Table 3. Agricultural Quantity, Price and Productivity Indexes for Selected Research and Extension Expenditure Strategies

	Research and Extension Expenditures		Indexes		
Year	1980 Dollars	Discounted to 1980 (6%)	Quantity	Price	Productivity
	------- ($ million) -------				
I. Base situation					
1981	1,620.83	1,529.08	129.06	248.81	120.97
1984	1,759.35	1,393.58	134.56	251.69	126.16
1987	1,917.03	1,274.94	140.81	253.55	131.59
1990	2,108.08	1,177.15	147.38	255.40	137.08
Ten-year total	18,471.66	13,407.58			
II. Ten percent below base for 3 years and then above base					
1981	1,458.75	1,376.17	129.06	248.87	120.96
1984	2,004.16	1,587.49	134.53	251.86	126.09
1987	2,154.17	1,432.66	140.82	253.45	131.58
1990	2,351.72	1,313.20	147.47	254.93	137.24
Ten-year total	19,691.06	14,120.99			
III. Ten percent below base for 3 years and then return to base					
1981	1,458.75	1,376.17	129.06	248.87	120.96
1984	1,759.35	1,393.58	134.52	251.93	126.07
1987	1,917.03	1,274.94	140.76	253.82	131.44
1990	2,108.08	1,177.15	147.34	255.60	136.93
Ten-year total	17,995.95	12,984.17			
IV. Ten percent below base situation for 10 years					
1981	1,458.75	1,376.17	129.06	248.87	120.96
1984	1,583.42	1,254.22	134.51	251.98	126.06
1987	1,725.33	1,147.45	140.71	254.12	131.34
1990	1,897.27	1,059.44	147.23	256.17	136.67
Ten-year total	16,624.49	12,066.82			

The first hypothetical case of underfunding (relative to the base situation) is when policy makers decide to reduce research and extension expenditures 10% below the base level for three years and then spend enough during the later part of the ten-year period to generate the same level of consumer surplus as the base level. The expenditures required to achieve this strategy are shown as alternative II in table 3. These results indicate that it is possible, although costly, to overcome underfunding for a limited number of years. In the first three years this strategy would reduce expenditures $476 million. However, expenditures would have to be increased $1,219 million ($713 million discounted) above the base in order to leave consumers unaffected. Thus each dollar that policy makers try to save now ultimately will cost the government $2.56 ($1.50 discounted).

The second case of underfunding involves a 10% reduction in expenditures for the first three years followed by a return to the base level of expenditures for the fourth and remaining years with no recovery attempt being made. The effect on productivity, prices, and farm production are shown as alternative III in table 3. Productivity and production are less than the base situation, while equilibrium prices are higher. Although these differences may not appear very great, they must be put into perspective. These figures represent total agricultural production in the United States. Even slightly higher prices translate into a substantial reduction in consumer welfare. The estimated reduction in consumer surplus is small in the first few years, but as the cumulative effect of underfunding is felt, the magnitude of consumer surplus reduction rises substantially. Over the ten-year period the consumers of U.S. agricultural products would experience $1.86 billion in reduced consumer surplus due to underfunding.[5] The present value of this loss in consumer surplus is $1.30 billion compared to the present value of government budget savings of $0.42 billion. From these figures, it is evident that this strategy would result in a loss of consumer surplus of $4.39 ($3.07 discounted) for consumers for each dollar saved by the government.

A final underfunding case involves establishing and maintaining a lower level of funding than in the base situation. In this case, research and extension expenditures are 10% below the base situation for the entire period. This expenditure pattern as shown by alternative IV in table 3 has a greater effect on farm output and prices than a temporary reduction. The reduction in consumer surplus which results from this permanent reduction in expenditures is shown in figure 1. Although initially the savings in government expenditures are higher than the loss in consumer surplus, the reduction in consumer surplus increases rapidly through time and soon far outweighs the budget savings. This relationship can be explained by the lagged effect of research and extension expenditures on productivity. Over the period 1981–2000 (figure 1), consumer surplus would be reduced $11.8 billion ($5.7 billion discounted). Yet, the reduction in government expenditures would amount to only $4.2 billion ($2.3 billion discounted).

Implications

Agricultural research and extension expenditures in one year will affect agricultural productivity and, hence, farm and food prices for many years in the future. The contribution of these expenditures to agricultural productivity is relatively small in the first few years, in-

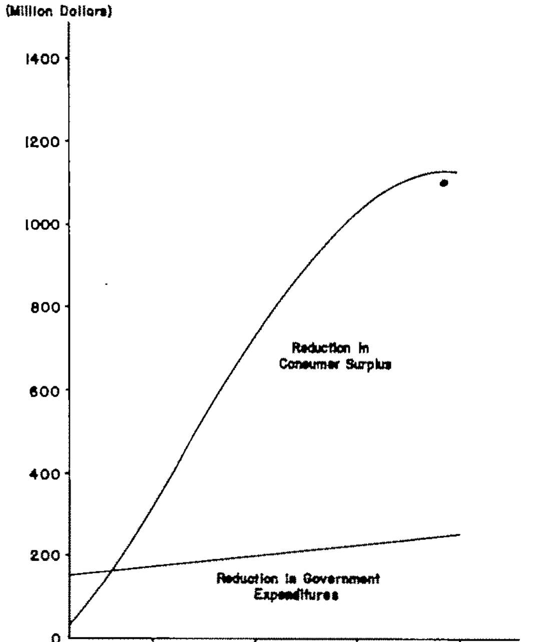

Figure 1. Long-run impact of a reduction in funding for agricultural research and extension

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[5] Approximately three-fourths of the loss in consumer surplus is expected to accrue to U.S. domestic consumers, while the remainder is expected to accrue to foreign consumers.

creases to a maximum in the sixth and seventh years, and then declines through the fourteenth year. In choosing the appropriate level of expenditures in each year, policy makers should take into account multiperiod effects. Since expenditures in each year will affect productivity in later years, inadequate funding of agricultural research and extension activities in one period will be very difficult to overcome later. The problem of selecting the optimal level of expenditures is also stochastic. Therefore, the uncertainty surrounding research breakthroughs makes it impossible to control future outcomes exactly.

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Disequilibrium Market Analysis: An Application to the U.S. Fed Beef Sector

Rod F. Ziemer and Fred C. White

In this paper current theory and estimation procedures are applied in an analysis of disequilibrium price behavior in the U.S. fed beef sector. Although tests of equilibrium versus disequilibrium hypotheses are not well developed, results indicate the possible presence of disequilibrium prices in the market for fed beef; at least the hypothesis of significant disequilibrium could not be rejected.

Key words: disequilibrium, fed beef, maximum likelihood estimation.

The purpose of this study is to consider the nature of price adjustments in agricultural commodity markets in light of recent developments in disequilibrium theory and estimation. By disequilibrium we mean that market transactions occur at prices which do not clear the market, so that some buyers or sellers are not able to trade desired quantities at the prevailing price. Given the possibility of disequilibrium prices, an important issue regards the nature of price and quantity adjustments in the market. Generally, a basic economic assumption is that at the market price, quantity transacted is equal to the minimum of demand and supply (Clower), or in other words, the short side of the market dictates the level of exchange. Several mechanisms regarding dynamic price adjustments in a disequilibrium model have been proposed assuming either market price is predetermined or endogenous (see Ito). A brief review of current disequilibrium theory and empirical applications can be found in Gourieroux, Laffont, and Monfort. We propose that in certain agricultural markets observed prices may not be associated with an identity of demand and supply. In this paper, the competitive equilibrium hypothesis is discussed and analyzed with application to the U.S. fed beef sector.

In the next section, theoretical considerations are addressed. A distinction is made between dynamic equilibrium models and disequilibrium models in which markets are not assumed to clear continually. Causes of disequilibrium price behavior are discussed. Next, a model of fed beef demand and supply is estimated in a general disequilibrium framework. Finally, results are discussed and evaluated with suggestions made for further research.

Theoretical Considerations

Following Labys, consider the following general dynamic equilibrium model:

$$D_t = f(P_t, X_t) \tag{1a}$$

$$S_t = f(P_t, Z_t), \tag{1b}$$

$$P_t = f(dI_t, W_t), \tag{1c}$$

$$dI_t = I_t - I_{t-1} = S_t - D_t, \tag{1d}$$

where t represents time, D is demand, S is supply, P is price, Q is the quantity exchanged, I is the level of inventory and X, Z, and W represent appropriate exogenous factors. A primary feature of the model defined in (1) is that quantity demanded is not restricted to equal quantity supplied in any given time period. The level of excess demand, $D_t - S_t$, is assumed to be absorbed by inventory adjustments through the market clearing identity (1d). Therefore, there are two market-clearing adjustment mechanisms: price and inventory. The model allows for the possibility of excess demand so that D_t and S_t are not restricted to be equal; but, as in the traditional cobweb

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model, the market always clears—that is, no buyers or sellers are unable to achieve their desired level of transactions at prevailing prices in any given time period. Prices and inventories are always assumed to adjust sufficiently to result in market clearing. If the commodity of interest is one that is easily stored and quantities transacted do not vary significantly over time, the model described by (1) may accurately depict price behavior in the market. However, agricultural commodities are often highly perishable, particularly at the farm level. Furthermore, quantities marketed for many commodities often follow seasonal trends and production cycles (see Meadows). These and other natural phenomena, such as weather variability, can make inventory adjustments difficult in many agricultural markets. In the model defined above, if inventories do not vary or do not exist, it is assumed that price will adjust sufficiently to clear the market.

Following Quandt (1978a), the characteristic that distinguishes disequilibrium from equilibrium models is relaxing the assumption that both the quantity supplied and the quantity demanded are equal to the quantity transacted. The simplest disequilibrium model imaginable would consist of equations (1a) and (1b). However, such a model provides no information on what quantity will be transacted at nonequilibrium prices. If we assume that exchange is voluntary, the quantity transacted cannot exceed the minimum of quantities demanded and supplied, or $Q_t \leq \min(D_t, S_t)$. If exchange exhausts all mutually advantageous transactions, then $Q_t \geq \min(D_t, S_t)$. As noted by Grossman, combining both assumptions yields the condition

$$Q_t = \min(D_t, S_t). \tag{2}$$

This condition represents a formal statement of the notion that supply and demand schedules set limits within which fluctuations in observable price-quantity behavior will occur (Smith). The addition of equation (2) closes the model by unambiguously specifying the quantity exchanged at nonmarket clearing prices. A model consisting of equations (1a), (1b), and (2) indicates the effect of disequilibrium prices on the quantity exchanged but fails to describe the nature of buyer and seller behavior in periods when the market does not clear. Therefore, it is usually customary to include a Walrasian price adjustment mechanism in the model. Then a simple disequilibrium model can be written:

$$D_t = f(P_t, X_t), \tag{3a}$$

$$S_t = f(P_t, Z_t), \tag{3b}$$

$$Q_t = \min(D_t, S_t), \tag{3c}$$

$$dP_t = \lambda(D_t - S_t), \tag{3d}$$

where $0 \leq \lambda \leq \infty$, and all variables are as defined previously. Although it is possible to derive more sophisticated disequilibrium systems, this set of equations constitutes a fairly general model. Furthermore, if $D_t = S_t$ for all t, then (3) reduces to the competitive equilibrium model which is a special case of the disequilibrium model.

Disequilibrium in the Market for Fed Beef

In general, there are numerous possible causes of disequilibrium. Examples are inordinate weather, sudden changes in population or other demographic variables, and specific influences peculiar to a particular market (van Doorn). Barring artificial price-quantity constraints, ignorance on the part of buyers and sellers as to the true equilibrium price and shifting of market supply and demand curves would allow for the possibility of excess demand to occur (Hess). The idea that incomplete information can lead to disequilibrium price behavior has been often suggested (see, for example, Lancaster or Smith). Gordon and Hynes contend that incomplete information is the most tenable explanation of dynamic price behavior relationships and that disequilibrium involves some form of uncertainty regarding knowledge of demand and supply schedules. If prices are perfectly flexible, then exogenous market shocks may not necessarily lead to disequilibrium prices, given complete market information. Under conditions of incomplete information, product perishability and the long production cycle for some agricultural commodities may hamper desired short-run changes in quantity supplied and generate prices which fail to clear the market.

The U.S. beef sector is usually divided into two separate markets: fed and nonfed beef. Both share common causes of possible disequilibrium due to incomplete information. For example, extreme weather conditions, such as severe winters or droughts, may result in unplanned disruptions in quantities marketed, while long production cycles may limit the responsiveness of quantities marketed to rising prices. While the two markets are similar in some respects, they differ with regard to possible causes of disequilibrium price behavior. First, the final stage of the fed-beef production cycle does not show quick responsiveness to changes in demand. Short-run flexibility in quantity supplied is low because of the feeding cycle length and the high transactions costs of maintaining marketable livestock on feedlots. Sources of nonfed beef often have alternative production capacity such as dairy or breeding use. Consequently, short-run quantity adjustments probably are more price responsive for nonfed beef than for fed beef. Furthermore, the income elasticity of demand is much higher for fed beef than for nonfed beef (Arzac and Wilkinson, Freebairn and Rausser). The greater sensitivity of fed-beef demand to changes in income increases the chance of disequilibrium in the market for fed beef versus nonfed beef, particularly when slower supply adjustments characterize the fed-beef sector. Government involvement in the U.S. beef economy exemplified by the 1964 import bill PL 88.482 and the 1971 to 1974 wage and price controls also may cause disequilibrium prices (Multop and Helmuth).

Some firms in the fed-beef market may be able to obtain market information and react before the information becomes available to all other market participants. Ward (1980) concluded that carcass beef price changes do not reflect all available new market information. Market concentration of buyers and sellers of fed beef may provide an opportunity for some firms to take advantage of limited market information, especially on a local basis. Meisner and Rhodes and Multop and Helmuth recently found evidence of such behavior by U.S. cattle feeders and beef packers.[1] Also, Ward (1979) found that cattle buyers and sellers often possess varying amounts and types of information about prices and market conditions. Thus, some individuals often have an information advantage. Such information differences among market participants can lead to price deviations away from competitive levels when markets exhibit a lack of price and quantity flexibility.

In general, if prices are highly flexible, even markets characterized by inelastic short-run supply can still exhibit market-clearing behavior, given complete information. However, a lack of flexibility in prices and quantity supplied and differences in information availability among market participants (characteristics apparent in the fed-beef market) can prevent a market from achieving equilibrium. In sum, disequilibrium prices in the U.S. fed beef sector seem likely because of (*a*) information not uniformly or completely distributed among market participants, (*b*) increasing concentration on both the buyer and seller sides of the market, (*c*) a lack of short-run production flexibility, and (*d*) an increasing level of government involvement.

Empirical Model and Estimation

In this section we construct a simple model of the U.S. fed-beef market consisting of four equations. The equations describe the demand and supply of fed beef, the observed quantity of fed beef transacted, and price adjustment in the market. Quarterly observations over the period 1965–79 were used in the estimation.[2]

Demand is a function of own price, substitute prices, and income. The demand equation can be written:

$$(4) \quad D_t = \alpha_0 + \alpha_1 UCP_t + \alpha_2 HP_t + \alpha_3 Y_t + \alpha^* P_t,$$

where D_t is the quantity demanded of fed beef, UCP_t is the price of utility cows, HP_t is the price of hogs, Y_t is income, P_t is the price of fed beef, and the α's represent parameters to be estimated. Supply of fed beef is a function of own price, prior placements of cattle on feed, and the price of corn. The supply equation is

$$(5) \quad S_t = \beta_0 + \beta_1 PC_{t-2} + \beta_2 C_t + \beta^* P_t,$$

where S_t is the quantity supplied of fed beef, PC_{t-2} is the number of cattle previously placed on feed, C_t is the price of corn, and the β's are parameters.

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[1] As of 1978, the weighted-average four-firm state-level concentration ratio in the U.S. fed-beef slaughtering industry had increased to 66% while the national four-firm concentration ratio had increased to 32% (see Multop and Helmuth). On the seller side of the market, over the 1962–73 period, the total number of cattle fed by farmer-feeders remained unchanged, while the total number fed by commercial feeders rose over 200% (Meisner and Rhodes).

[2] Data for the analysis were from: USDA *Agricultural Prices*, *Livestock and Meat Situation*, *Livestock and Meat Statistics*, U.S. Department of Commerce *Handbook of Cyclical Indicators*, FRS *Federal Reserve Bulletin*, and USDA worksheets.

In a disequilibrium model the observed quantity exchanged is not given by the intersection of demand and supply. In this model, the quantity transacted is assumed to be associated with the short side of the market so that the third equation in the model is given by (3c). The final equation in the model is given by (3d), which describes price adjustment in the market. We assume the following price adjustment mechanism: $dP_t = P_t - P_{t-1}$, which implies that price adjusts during the period but does not generally succeed in clearing the market (Fair and Jaffee).

Estimation

For estimation purposes, we can compactly write our model as follows:

$$(6) \qquad \begin{aligned} D_t &= X_t\alpha + P_t\alpha^* + u_t, \\ S_t &= Z_t\beta + P_t\beta^* + v_t, \\ Q_t &= \min(D_t, S_t), \\ dP_t &= \lambda(D_t - S_t), \end{aligned}$$

where $t = 1 \ldots T$, X_t and Z_t are defined in (4) and (5), α and β are conformable parameter vectors, $dP_t = P_t - P_{t-1}$, and u_t and v_t are normally distributed random error terms with zero means and variances σ_u^2 and σ_v^2. An immediate estimation problem concerns the observability of D_t and S_t. Unlike an equilibrium model, D_t and S_t cannot both be strictly identified with observed quantity, Q_t. Fair and Jaffee suggest eliminating D_t and S_t from the model by reducing the system in (6) to the following two equations:

$$(7) \qquad \begin{aligned} Q_t &= X_t\alpha + P_t\alpha^* - \lambda^* d_t + u_t, \\ Q_t &= Z_t\beta + P_t\beta^* + \lambda^* s_t + v_t, \end{aligned}$$

where $\lambda^* = (1/\lambda)$,

$$d_t = \begin{cases} dP_t \text{ if } dP_t > 0, \\ 0 \text{ otherwise, and} \end{cases}$$

$$s_t = \begin{cases} dP_t \text{ if } dP_t < 0, \\ 0 \text{ otherwise,} \end{cases}$$

so that all variables are observable for $t = 1 \ldots T$. Amemiya shows that the parameters of (7) can be consistently estimated by two-stage least squares in which predicted values are substituted for all values of right-hand-side endogenous variables including d_t and s_t. Although consistent, the two-stage least squares estimator in this case is not asymptotically efficient and there is no guarantee that the two resulting estimates of λ^* will be equal. For these reasons the maximum likelihood estimator, which is consistent and asymptotically efficient for this model under general conditions (Amemiya), is used for estimating the parameters in (6).

The appropriate likelihood function for the model can be found in Laffont and Garcia (p. 1202). Estimation of the model was accomplished following the gradient search procedure suggested by Berndt et al., in which

$$(8) \qquad \theta_{n+1} = \theta_n + \gamma_n H_n g_n,$$

where $\theta = [\alpha, \alpha^*, \beta, \beta^*, \lambda, \sigma_u^2, \sigma_v^2]$, $0 < \gamma_n < 1$ where γ_n is the step-size for the nth round estimate of θ, $g = [\partial L/\partial\theta_n]$, L is the likelihood function, and

$$H_n = \sum_{i=1}^{T} \left[\frac{\partial \mathrm{L}_i}{\partial\theta_n}\right] \left[\frac{\partial \mathrm{L}_i}{\partial\theta_n}\right]',$$

where $[\partial \mathrm{L}_i/\partial\theta_n]$ is the gradient vector for the ith observation evaluated at θ_n. An acceptable choice for γ_n satisfies the condition:

$$(9) \qquad \theta \leq h(\theta_{n+1}, \theta_n) \leq 1,$$

where

$$h(\theta_{n+1}, \theta_n) = \frac{L(\theta_{n+1}) - L(\theta_n)}{\gamma_n\, d'_n\, g_n},$$

where $d_n = H_n g_n$. Satisfying condition (9) guarantees solution improvement at each iteration; proof of convergence is given by Berndt et al. (p. 656).

Results

Numerical results appear in table 1. Parameter estimates for the model assuming equilibrium are also presented in which the last two equations of (6) are replaced by the market-clearing identity $Q_t = D_t = S_t$. The equilibrium model was estimated using two-stage least squares (2SLS). For the disequilibrium model, thirty-nine observations were identified with the supply curve ($dP_t > 0$) and twenty-one observations were identified with the demand curve ($dP_t < 0$). Maximum likelihood results for the disequilibrium model appear under the heading *MLE*. For all estimates, asymptotic standard errors appear in parentheses.[3]

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[3] To derive an estimate of the standard error of $\lambda^* = 1/\lambda$, the general asymptotic covariance matrix of a nonlinear vector function of a maximum likelihood estimator $\hat{\Theta}$, say $\Psi(\Theta)$, is used:

$$D\left[-\frac{\partial^2 L}{\partial\hat{\Theta}\partial\hat{\Theta}'}\right]^{-1} D'$$

where L is the likelihood function for the model and D denotes the derivative of $\Psi(\Theta)$ with respect to Θ (Theil, p. 373).

Table 1. Results for a Demand and Supply Model of the U.S. Fed Beef Sector, 1965–79

	Estimated Coefficients	
Variable	*TSLS*	*MLE*
Demand equation		
Constant	588.0250	1,381.1400
	(705.3493)	(522.9030)*[a]
Price of fed beef, P_t	−72.0056	−55.1454
(Omaha 900–1,100 lb. choice, $/cwt)	(38.6898)	(13.6897)*
Price of utility cows, UCP_t	89.7490	66.7723
(Omaha, $/cwt)	(37.1072)*	(4.9422)*
Price of hogs, HP_t	−9.1478	−17.3468
(Barrows and gilts, 7 mkts., $/cwt)	(13.7149)	(5.1964)*
Per capita personal income ($1,000), Y_t	172.2290	152.0580
(deflated by CPI)	(25.8488)*	(13.5731)*
Supply equation		
Constant	4,194.9200	3,873.0000
	(376.2395)*	(299.7190)*
Price of fed beef, P_t	43.3438	60.3543
(Omaha 900–1,100 lb. choice, $/cwt)	(10.6434)*	(8.9843)*
Placement of cattle on feed, PC_{t-1}	.1526	.2013
(1,000 head)	(.0621)*	(.0188)*
Price of corn, C_t	−42.0864	−68.9145
(received by farmers, $/10 bu.)	(10.6434)*	(8.6626)*
Price adjustment equation		
λ		.0111
		(.0009)*
λ^*		90.3000
		(7.2833)*

Note: Dependent variable—fed-beef marketings (carcass weight, m. lb.); number of observations = 60.

[a] Asterisk indicates significantly different from zero, $\alpha = .05$ (standard errors in parentheses).

All estimated parameter values show theoretically correct signs except for the estimate on the price of hogs, HP_t, in both estimated equations. All parameter estimates in the disequilibrium specification are significantly different from zero at usual significance levels. Based on the parameter estimates for P_t and Y_t in the demand equation, price elasticity of demand and income elasticity are slightly higher under the equilibrium model than those implied by the disequilibrium specification.

In the disequilibrium model, the estimate of the price adjustment coefficient, λ, is positive as theoretically expected and significantly different from zero, implying the null hypothesis of no price adjustment or permanent disequilibrium ($\lambda = 0$) can be rejected. Appealing to the asymptotic normality of maximum likelihood estimates, Fair and Jaffee suggest that the hypothesis of perfect or continuous equilibrium can be tested by testing the hypothesis that $\lambda^* = 1/\lambda = 0$. The estimate of λ^* in table 1 is significantly different from zero. This result indicates that price may not be sufficiently flexible in the U.S. beef economy so as to insure a state of continuous equilibrium. However, Quandt (1978b) concluded in a Monte Carlo study that the ratio of the maximum likelihood estimate of λ^* to its asymptotic standard error may not be well approximated by a normal distribution, and so the test leads to a high probability for type I error. Alternatively, Quandt concluded that the Fair and Jaffee test gives satisfactory inferences when the null hypothesis of equilibrium is false. Other tests of equilibrium versus disequilibrium have been suggested (Bowden, Quandt 1978b), but there is no generally accepted approach to the problem.

Besides specification error, the empirical consequences of specifying a disequilibrium model as an equilibrium model relate largely to how well the model performs in forecasting market price. To compare the forecasting performance of the estimated models, two well-established criteria were used. The first is root-mean-squared error (*RMSE*) based on the reduced form of (6) solving for current price P_t. The second involves auxiliary regression equations for estimated and actual prices of the form:

$$\hat{P}_t = \phi_1 + \phi_2 P_t + e_t, \tag{10}$$

where $\hat{P}_t$ is estimated price from the reduced form of (6) based on parameter estimates of the model (see table 1), P_t is the actual observed price, ϕ_1 and ϕ_2 are parameters, and e_t is a normally distributed random-error term with zero mean and finite variance (Yeh). In such a goodness-of-fit model, a perfect fit would result in $\phi_1 = 0$, $\phi_2 = 1$, and $R^2 = 1$.

In table 2, *RMSE* along with parameter estimates and R^2 based on equation (10) for the three models in table 1 are presented. Values for t-statistics for the null hypotheses that $\phi_1 = 0$ and $\phi_2 = 1$ appear in parentheses. Besides the available sample observations for the period 1965–79, observations outside the sample period for the first two quarters of 1980 also were used in the calculation of *RMSE* and the estimation of the goodness-of-fit equation (10). Referring to table 2, *RMSE* was slightly lower for the equilibrium model, *TSLS*, than for the disequilibrium model, *MLE*. For the price equation (10), the hypotheses concerning the values of ϕ_1 and ϕ_2 could be rejected for both models given $\alpha = .10$. R^2 was slightly higher for the disequilibrium model. Overall, these results fail to indicate that either of the models yield more accurate price forecasts when historically evaluated over the period of analysis. However, disequilibrium models would not generally be expected to outperform equilibrium models in markets that normally exhibited equilibrium behavior, especially when evaluated over long historical periods. Alternatively, disequilibrium models should yield more accurate price forecasts during periods of significant market disequilibrium.

Table 2. Auxiliary Price Equation Results and RMSE for Estimated and Actual Values of P_t

		Price Equation Results		
Model	*RMSE*	ϕ_1	ϕ_2	R^2
1965–1980 (II)				
TSLS	.5283	2.89 (1.73)*[a]	.92 (1.95)**	.89
MLE	.5384	4.85 (3.72)*	.83 (5.36)**	.92
1971–1974				
TSLS	1.1843			
MLE	.7653			

[a] Single asterisk indicates significantly different from zero, $\alpha = .10$; double asterisk, significantly different from one, $\alpha = .10$.

To test this hypothesis in the market for fed beef, *RMSE* was calculated for the equilibrium and disequilibrium specifications over the period 1971–74, during which government wage and price controls were administered. Multop and Helmuth (1980) have argued that beef prices were significantly distorted from equilibrium levels during this period. Results of the analysis, presented in table 2, show the disequilibrium model yielded substantially more accurate price forecasts over the 1971–74 period.

Conclusions

Although disequilibrium market analysis is still in an early stage of development, specification and estimation of relatively simple models are possible. In this paper we apply current theory and estimation procedures to the U.S. fed-beef sector. Although tests of equilibrium versus disequilibrium hypotheses are not well developed, results indicate the possible presence of disequilibrium price behavior in the market for fed beef. At least the hypothesis of significant disequilibrium could not be rejected.

The disequilibrium model yielded more accurate fed-beef price forecasts than the equilibrium model over the 1971–74 period during which government wage and price controls were in effect. These results support the idea that disequilibrium models can provide valuable information concerning the effect of institutional price-quantity distortions in the market. Even in cases where equilibrium models predict as well as disequilibrium models when evaluated using long periods of historical data, determination of extreme market disturbances may more accurately be estimated in a disequilibrium framework. In situations where proposed agricultural policy might severely affect commodity markets, a disequilibrium model may provide policy makers and analysts with useful information concerning the speed with which normal competitive behavior will resume.

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Price Trends at Livestock Auctions

Steven T. Buccola

Auction bidders may pursue a large number of reasonable bidding strategies, including those that are risk-neutral and risk-averse. Risk-averse bidders are especially tempted by the auction process to discriminate against themselves, that is, to offer prices close to their reservation prices or target prices. Self-discrimination, in turn, usually implies that quality-corrected prices of individual lots trend downward as the sale proceeds. The empirical evidence for downtrending prices at selected yearling steer sales is examined. Implications are then drawn for auction pricing efficiency and equity.

Key words: bidding strategies, livestock auctions, price discovery, price discrimination.

One task of agricultural marketing research is to investigate the impact of price discovery mechanisms on price behavior and accuracy. An important subset of this research has focused on the auction method of price discovery, either to evaluate the performance of alternative auction rules or to describe how traders behave, or should behave, at auctions. The former category includes studies by McPherson, Butler, Vickrey, Smith, and Frahm and Schrader. The latter includes those by Traylor, Duncan, Sosnick (1963, 1965), and Whan and Richardson.

A property often ascribed to the auction process is that it encourages buyers to discriminate against themselves. If only one lot is offered for sale in an ascending (English) auction, it will be sold, in the absence of collusion, at a price just above the second highest reservation price of all bidders present. As a consequence, nearly all the buyer's surplus is extracted by the seller.

More commonly in English auctions of agricultural goods, numerous lots are offered for sale serially. Because the demand for each lot cannot be predicted with certainty, noncollusive, nonsatiated buyers will be tempted to offer their full reservation price on the next lot tendered. If buyers fall prey to this temptation and if reservation prices among buyers differ, realized prices of homogenous lots will decline during an auction as the most eager buyers become satiated and cease bidding. Hence, the presence of declining prices at an auction of homogenous lots suggests that buyers are succeeding in discriminating against themselves.

This paper considers arguments for and against the presumption of declining prices at English auctions. It then investigates auction sales of feeder yearling steers in Virginia to test the declining-price hypothesis. Tentative conclusions are drawn about the pricing accuracy of livestock auctions and about equity among cattle buyers and sellers.

Conceptual Issues

Sosnick (1963) suggested that, although inequality of buyers' reservation prices tends to promote a price downtrend during an auction, other factors act to nullify this effect. First, buyers may come and go during the auction, interrupting a downtrend. Second, obvious quality differences between successive lots can obscure differences in buyers' valuations of any given lot. Third, early in the sale, buyers will not usually offer their full reservation price, but rather the average price they expect to occur later in the sale.

The last argument is similar to Vickrey's, in which each of n expected-profit-maximizing bidders draws from the same uniform probability distribution a valuation of two identical and consecutively offered lots. Optimal strategy requires that each bidder offer the same average maximum bid for both lots. Thus, if

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bidders with linear utility each pursue an optimal strategy, the average realized price of both lots will be equal.[1] Even if the strict assumptions of perfect rationality and a common uniform probability distribution were relaxed, one could argue (with Sosnick) that bidders' forecasts of the average price later in the sale are likely to depend upon prices realized early. Many initially unsuccessful bidders may then revise their forecasts upward as the sale proceeds, possibly overwhelming any price downtrend caused by satiation of initially successful buyers.

A contrary insight into auction pricing behavior is provided by Smith's experiments in which students acted as buyers and sellers of fictitious homogenous lots. Each seller was assigned the same perfectly inelastic supply schedule with the same minimum price, and each buyer was assigned the same perfectly inelastic demand schedule with the same (higher) maximum price. Aggregate supply was greater than aggregate demand so that, at the equilibrium price (the sellers' minimum price), all economic rent accrued to buyers. In each of six auction sessions conducted, transaction prices approached the equilibrium price from above. The inference is that, early in the sale, overeager buyers permitted economic rent to be extracted from them. The rate at which prices subsequently declined was proportional to the current excess rent in the market. In other words, buyers' initial attempts to bid lower prices met with little resistance because seller profits were high. Resistance increased as seller profits diminished, and resistance became absolute when seller profits vanished at equilibrium. Frahm and Schrader found a similar tendency for experimental auction prices to approach equilibrium from above in both English and Dutch systems.

An interesting implication of both experimental studies is that downtrends resulted from the way in which bidders collectively searched for the equilibrium price. The downtrends did not result from inequality of bidders' reservation prices or demand schedules because such inequalities were not present. A sufficient explanation for the observed downtrends, not depending on unequal reservation prices, is that although all buyers would like to pay the lowest price possible, some wish to minimize the risk of failing to make any purchase during the session. The latter individuals are prepared to offer their full reservation price early in the sale. This results in initially high prices and early satiation of the most risk-averse buyers. The remaining buyers are those willing to risk a test of their hypotheses about the excess supply function at the market.[2] They do so by bidding closer to their expectation of the equilibrium price, the least risk-averse being willing to bid the lowest of all. Thus, buyers are satiated in the order of their risk aversion, producing a price downtrend.

In contrast, Vickrey's and Sosnick's supposition that buyers seek to minimize expected payout at an auction, subject perhaps to acquiring a given number of lots, could not explain the consistent occurrence of Smith's downtrends. Having linear utility, each buyer would be ready, early in the sale, to offer a price no higher than his expectation of the equilibrium price. Such strategy might result in short-run disappointment, but greatest profits in the long run.

In actual auction markets, of course, buyers generally differ in reservation prices they assign to specific lots because quality imputations and expectations of net resale value are partially subjective. With unequal reservation prices, strong risk aversion among buyers is sufficient to explain a downtrend in prices even if buyers do not form an estimate of the excess supply function as the sale proceeds. This may be shown most clearly in cattle auctions, where buyers often have strong incentives to realize short-run gains. For example, order buyers of cattle are often directed to purchase a specific number of head in a given grade, weight, and sex class, at an average price not to exceed a stated maximum. Because these buyers are paid on a per head-purchased basis, they reasonably wish to minimize the probability of not meeting the volume target set by their clients, subject to the client's reservation price. Under these conditions, the order buyer will prefer the next lot to any later lot if it is not bid higher than his reservation price. The aggregate result is that buyers remain eager bidders throughout the sale, satiating themselves in order of their reservation prices and producing a price downtrend.

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[1] Vickrey's proof assumed that each bidder will be willing to pay a maximum price b_i that is a function $b_i(v_i)$ of the valuation each has drawn. Each function $b_i(v_i)$ is the same for all bidders. In addition, initial bids on the first lot are sealed.

[2] One such hypothesis is that the average demand function of the buyers present is the same as one's own. The excess supply function is then the vertical supply of cattle offered for sale that day, truncated at the supposed seller reservation price, minus n times one's own demand function.

Another reasonable, risk-averse buyer objective would give a similar result. Feedlots or packers with high fixed costs may wish to minimize the probability of having to exceed a target purchase price for cattle, subject to the restriction that purchased volume reach a given quota. In this case, the buyer prefers to raise any bid below his target price because, if his bid is successful, the chance of exceeding the target price vanishes. The result is that buyers again satiate themselves in order of their target prices. Requiring that a purchase quota be satisfied may, however, have more complicated effects on price trends than would imposing a rigid reservation price. Some cattle buyers, finding their purchase quotas unfilled near the end of a sale, would be willing to bid at prices higher than their original target prices. This would produce the late uptrend in auction prices as recorded by Kuehn at West Virginia livestock auctions.

Previous Empirical Work

In summary, one cannot reliably forecast the direction in which quality-constant prices would trend during an auction without information about buyer reservation prices or demand schedules, buyers' arrivals and departures during bidding, buyer objectives, the aggregate excess supply in the market, and buyers' hypotheses concerning that excess supply. A large combination of factors could result in either price uptrends or approximately stable prices. But we expect quality-constant prices to trend downward more often than not. This is because most buyers probably are risk-averse in varying degrees and have unequal reservation prices. Each of these characteristics is conducive to a price downtrend.

The few empirical studies available tentatively confirm the tendency of quality-constant or -corrected prices to drop as the sale proceeds. For example, in Traylor's analysis of commercial-grade slaughter-calf auction prices in Louisiana, prices generally declined during three of seven sales observed. In the four remaining sales, prices first rose and then fell, a phenomenon Traylor ascribed to late arriving and early departing buyers.

Sosnick's (1965) own study of bull sales in California provides more detailed evidence in this direction. After stratifying his sample into lots of equivalent grade and size, Sosnick found that mean price changes between one lot and the next were zero if the same buyer bought both lots and −\$10.00 if a different buyer bought each lot. If the probability were, say, .27 that the buyer of any two consecutive lots was the same person (a situation that might arise if there were relatively few large buyers present), the average price change from one lot to the next would have been −\$7.30, or about 1.5% of the average bull's price. Therefore, some overall price downtrend seemed to predominate.

Finally, a moderate and statistically significant aggregate downtrend in feeder calf prices at 1976–77 West Virginia auction sales was reported by Kuehn. Although Kuehn accounted for weight, grade, and breed effects as well as lot position, he did not indicate the extent to which these characteristics may have been confounded with lot position. Nor did the study provide information about price movements in individual sales.

In the following, I analyze price trends at individual auction sales of fall yearling steers during the period 1958–79. The analysis concentrates on sales at the Winchester market in northern Virginia. Because yearlings in various weight, grade, and breed categories were involved and because the animals were sold in numerous lot sizes, the methods used for generating quality-constant prices are discussed first.

Sample and Methods

State-graded yearling sales are held several times each fall at the Winchester market. Virtually all animals are destined for feedlots, primarily in Pennsylvania and the eastern Corn Belt. The larger buyers purchase on order for feedlot clients. Most other buyers are feedlot employees or farmer-feeders. Animals are sold in commingled lots averaging ten head and ranging from one to sixty head per lot; each lot is roughly homogenous in weight, grade, and breed. Steer weights generally range from 650 to 1,000 pounds. About 90% of the animals fall into grades choice (large and medium no. 1's), good (small no. 1's), and medium (large and medium no. 2's); the remainder fall into lower grades. During the 1960s, the predominant breeds were

Hereford and Angus; in the 1970s these were joined by Angus-Hereford crosses and Charolais cattle. A few lots involving lower grades and minor breeds, such as Shorthorns and their crosses, were deleted from the sample.

The overall strategy of estimating the price effect of a lot's position in an individual auction session was straightforward. Per hundredweight price (P) realized for a lot was regressed against the average steer weight (W) in the lot; the number of head (LS) in the lot; zero/one designations representing good (G) and medium (M) grade groups and Angus (A), Angus-Hereford (AH), and Charolais (C) breed groups; and the order (LP) in which the lot was sold that day or the order in which it was sold within a particular grade that day. In symbols,

$$(1) \quad P = P(W, LS, G, M, A, AH, C, LP),$$

where the choice grade and Hereford breed are used as base groups. The effect was to regress prices corrected for weight, lot size, grade, and breed factors against either of the latter lot position variables, which were also corrected for such factors.

A problem with this approach is that, in all Virginia state-graded feeder cattle sales, lots are purposely offered for sale in an order that is, to some extent, determined by weight, grade, and breed. Thus, measures of the latter factors will be correlated with lot position, thereby decreasing the precision of OLS estimates of the lot position effect compared with results one might obtain with uncorrelated data.

Choice of Samples

The first approach to overcome the multicollinearity problem was to select an auction market with the least-pronounced tendency to offer lots in the order of intrinsic value.[3] In state-graded sales at most Virginia markets, higher-grade cattle are offered for sale before lower-grade cattle and, within each grade category, cattle are offered in order of ascending weight (hence usually descending value per hundredweight). For these markets, the negative correlation between lot position and intrinsic value per hundredweight is quite strong. But Winchester market sales are organized so that all choice Angus are first offered in order of ascending weight, followed by choice Herefords, choice Charolais, and choice Angus-Hereford crosses, each in ascending weight. This order is then repeated for the good and medium grades. Fortunately, only a slight uptrend in value is associated with such ordering of breed types, so that within a single grade one would not anticipate a strong linear correlation between intrinsic value and lot position.

Therefore, I defined lot position as the order in which a lot was offered within a particular grade, not within the entire day's sale. This definition can be defended because most feeder cattle buyers intend to purchase animals only of a particular grade. At least they view their demands for different grades as distinct from each other. Hence the effect of lot position on price was expected to be distinct within each grade offering.

Extent of Multicollinearity

Two indicators were used to assess multicollinearity in the sample selected: (a) simple correlation coefficients of the explanatory variables and (b) the square root of the ratio of the largest to the smallest eigenvalue of each auction sale's standardized $\mathbf{X'X}$ matrix. The first approach, an often-used but limited tool, revealed frequently high negative correlations between the lot position (LP) and lot size (LS) variables and between the lot position and the Angus dummy (A) variable. The former reflects the relatively small lots in which heavier cattle and Charolais cattle are marketed, each having late sale positions. The latter occurs between any trendlike variable and a dummy variable in which all 1.0's precede all zeros.

The second approach offers a better measure of the degree to which multicollinearity is likely to affect the stability of least squares estimates (Wichern and Churchill). If the matrix $\mathbf{X}$ of explanatory variables is orthogonal, all eigenvalues of $\mathbf{X'X}$ are 1.0. Therefore, the square-root ratio of the largest to the smallest is also 1.0. As $\mathbf{X}$ becomes increasingly ill-conditioned, the ratio rises. The right-hand column of table 1 contains the square-root eigenvalue ratios for the eight-factor samples analyzed in this study; they range from 3 to 19.7. Belsley, Kuh, and Welsch (pp. 98–159) have shown that ill-conditioning of $\mathbf{X}$ begins to affect the stability of least squares estimates when such ratios reach the neighborhood of 15.[4] Thus, it appears that the sample screening was successful in avoiding serious multicollinearity in all but a few instances.

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[3] Intrinsic value is the expected per hundredweight value of the animal to a feedlot operator, given current feed and expected slaughter cattle prices.

Model Specifications

On this basis, I decided to rely principally on OLS fits of equation (1) to estimate lot position effects. In a subsequent model specification, lot size and the Angus dummy were removed as explanatory variables in order to observe the sensitivity of lot position effect estimates to these removals. Linear OLS estimates of equation (1), with eight factors, are referred to below as OLS1. Estimates of equation (1) with LS and A removed (six factors) are referred to as OLS2. For the samples with especially high eigenvalue ratios, ridge estimates $\beta_r(k) = (\mathbf{X}'\mathbf{X} + kI)^{-1}X'Y$ of equation (1) also were calculated for comparison (Dossin, Pierce, Gunst).[5]

Results

Mean lot position effects at each of forty-two fall yearling steer sales in Winchester, Virginia, 1958–79, are shown in table 1. Values in columns (2) and (3) are OLS coefficients of the lot position variable when this variable is expressed in linear form. Thus, the coefficients measure the mean price change in cents per hundredweight when lot position in a particular grade is advanced by one, holding other factors constant. R-squares corresponding to OLS1 are in column (4), and square-root ratios of the highest to lowest eigenvalue in each standardized eight-factor $\mathbf{X}'\mathbf{X}$ matrix are in column (5). Durbin-Watson tests revealed little evidence of serial correlation in residuals.

Table 1. Mean Effect of Lot Position on Lot Price per Hundredweight, State-Graded Yearling Steer Sales, Winchester, Virginia, 1958–79

Date of Auction (1)	Mean Effect[a] OLS1 (2)	OLS2 (3)	R-Square[b] (4)	Eigenvalue Ratio[c] (5)
9/26/58	5.4	−4.6*	.873	12.4
9/23/60	6.9	−3.5	.882	19.7
9/22/61	3.0	3.2*	.847	14.3
9/21/62	0.4	3.9*	.781	12.6
10/7/63	−3.5	−9.0	.848	6.6
9/18/64	14.4*	−9.3*	.893	12.6
9/17/65	−12.5	3.0*	.737	13.2
9/23/66	−10.9*	−7.7*	.864	3.0
9/22/67	0.6	7.8*	.891	14.1
11/3/67	1.1	−3.1	.859	4.6
9/20/68	−11.4*	−8.3*	.918	9.3
10/18/68	6.2	−7.7*	.876	10.2
9/19/69	−18.7*	−11.7*	.731	5.7
10/17/69	−6.0*	−6.7*	.889	4.2
9/18/70	−13.4*	−10.9*	.733	4.4
10/16/70	−2.0	−3.1	.908	15.3
9/17/71	−23.3*	−9.6	.822	10.8
10/15/71	−6.5	−5.0*	.783	7.1
9/22/72	−35.4*	−18.9*	.921	12.4
10/20/72	−8.7*	−6.3*	.907	5.7
9/21/73	−9.8	−14.6	.668	5.0
10/19/73	−22.5*	−18.6*	.911	9.4
9/20/74	−19.6*	−18.8*	.748	5.6
10/18/74	−2.1	−18.4*	.800	6.7
9/19/75	−12.3*	−20.0*	.739	4.1
10/17/75	−7.3	−9.8	.721	5.5
10/31/75	−50.7*	−59.1*	.862	5.7
11/14/75	−47.7*	−52.0*	.776	3.9
9/17/76	−27.1*	−25.4*	.697	5.7
10/15/76	−53.0*	−47.4*	.648	6.0
10/29/76	−37.5*	−27.8*	.810	5.1
11/12/76	−16.8*	−19.1*	.874	3.7
9/23/77	−26.9*	−29.7*	.675	5.0
10/21/77	−39.5*	−46.3*	.685	5.6
11/4/77	−10.0	−14.6*	.704	4.1
9/22/78	−8.8	−11.7	.773	7.1
10/20/78	8.7	−23.1	.768	7.6
11/3/78	2.3	1.3	.936	4.0
11/17/78	−97.9*	−60.1*	.782	16.3
9/21/79	−34.8*	−40.6*	.838	4.7
10/19/79	−15.8	−65.7*	.788	11.3
11/2/79	−21.0	−63.2*	.857	10.4
Means	−15.8	−15.9	.810	8.1

[a] OLS1 contains all explanatory variables, and OLS2 contains all but lot size and Angus dummy variables. Numbers shown in columns (2) and (3) are the average effect on price (¢/cwt) of advancing lot position within a grade by one. Coefficients significant at the 5% level in two-tail t-tests are asterisked.

[b] R-squares associated with OLS1.

[c] The square root of the ratio of the highest to the lowest eigenvalue of the standardized $\mathbf{X}'\mathbf{X}$ matrix, where $\mathbf{X}$ contains all explanatory variables listed in equation (1).

As expected, most lot position effects were negative. A considerable number of these effects were positive during the 1958–68 period, although most of the latter were not statistically significant at the 5% level in two-tail t-tests. Taking both OLS models together, 16% of the recorded effects were positive and 84% were negative. In the eight-factor model

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[4] The spectral condition numbers referred to by Belsley, Kuh, and Welsch are actually calculated from $\mathbf{X}$ itself, not from the eigenvalues of $\mathbf{X}'\mathbf{X}$. However, spectral condition numbers and the square root ratios discussed here are theoretically equivalent (p. 101).

[5] Here k was equated to $p\hat{\sigma}^2/\hat{\beta}'\hat{\beta}$, where p is the rank of $\mathbf{X}$ and $\hat{\sigma}^2$ and $\hat{\beta}$ are OLS estimates of $Y = 1\beta_0 + \mathbf{X}\beta + \epsilon$ (Hoerl, Kennard, and Baldwin). References to a standardized $\mathbf{X}$ matrix in this paper mean that $\mathbf{X}$ is adjusted so that, for each $\mathbf{X}_c$ of $\mathbf{X}$, $\mathbf{X}_c{}'1 = \bar{0}$, $\mathbf{X}_c{}'\mathbf{X}_c = 1$, and $\mathbf{X}'\mathbf{X} \neq \mathbf{I}$, is a correlation matrix of the explanatory variables.

(OLS1), lot position effects were statistically significant in 52% of the cases, with only one significantly positive. In the six-factor model (OLS2), the effects were statistically significant in 76% of the cases, only two of which were positive.

OLS estimates excluding the lot size and Angus dummy variables were frequently different from those including all variables. But, on average, the two OLS estimates of lot position effects were the same, indicating an approximate 16¢ per hundredweight reduction in sale price for each single advance in lot position within a grade. During the sample period, an average of twenty lots were offered in each of the three major grade categories on a given day. The OLS models suggest that, in an average sale, a lot sold last within a grade would bring $3.20 per hundredweight less than a lot sold first within that grade, all else constant. Importance of lot position clearly increased over the years studied, becoming especially strong after 1974.

Ridge estimates of the eight-factor model, derived for the highly collinear samples of 9/23/60, 10/16/70, and 11/17/78, had a strong impact only on the results for the 11/17/78 auction. The ridge estimate of the lot position effect on this day was −63.0 (with *k*-value .011). This is close to the OLS2 estimate and more plausible than the −97.9 OLS1 estimate.

Smith's conclusion that the tendency of auction prices to approach equilibrium varies with the current excess rent in the market implies that if prices begin above equilibrium, their path to equilibrium should be convex from below. The reasoning is that when prices are very high, excess rent is also high, implying a strong downward tendency in subsequent prices. As prices fall, excess rent diminishes, implying a further but weaker downward tendency. Prices would then be expected to approach gently, rather than plunge toward, equilibrium. In fact, quadratic OLS fits to the lot position variable were statistically significant for six of the forty-two sales studied. In only four of these cases did quality-corrected prices decline in a pattern convex from below. There was also little evidence of differences among grades in the linear lot position effect. In the few cases with such evidence, the lot position effect tended to be less negative the lower the grade.

Why do linear estimates of lot position effects shown in table 1 differ from one sale to the next? A promising hypothesis is that position effects become less negative as expected feedlot profits increase. With the prospect of increasing profits, cattle buyers probably become less concerned with violating reservation prices (which are to avoid financial loss) and more interested in completely utilizing their feedlot capacities (whose opportunity costs rise with profitability). When reservation prices are uppermost in buyers' minds, they are likely to satiate themselves in the order of these prices. But if purchase quotas are more important, incipient price downtrends often will be interrupted as those with unfilled quotas revise their initial, unsuccessful target prices upward.

This hypothesis was tested for the recent 1973–79 and 1975–79 periods by regressing OLS1 and OLS2 estimates of lot position effects (table 1, columns 2 and 3) against the preceding days' futures prices for five-month delivery cattle contracts and nearest-delivery corn contracts. Regardless of which lot position effect was used and which sample was analyzed, the signs of the cattle and corn price coefficients were correct, but none were statistically different from zero.[6] It appears that much of the interauction variation in position effects is determined by changes in the identities and strategies of active bidders, factors difficult to observe accurately. Because of this, lot position is likely to remain a poor indicator of sale price.

Conclusions

In theory, one should expect quality-corrected prices at a livestock auction sale to decline during the course of the sale more often than otherwise. An analysis of yearling steer sales conducted at Winchester, Virginia, during the period 1958–79 is consistent with this hypothesis. In these sales, the undeflated mean effect of advancing lot position within a grade by one was to decrease quality-corrected price by about 16¢ per hundredweight. This implies a $3.20 per hundredweight drop in price from first-lot to last-lot position in a typical sequence of twenty lots. Negative lot position effects have increased in recent years, partly because of inflation and higher cattle prices.

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[6] All data were deflated, then divided by the estimated standard errors of the lot position effects under the assumption that residual variances in an unweighted model would vary proportionately with the position effect variances (Johnston, pp. 214–17). At best, null hypotheses were rejected with a 15% chance of error.

During the period 1973–79, the mean position effect was −23.41 cents per hundredweight, or a $4.68 reduction across twenty lots. Because the mean yearling steer price at Winchester during this 1973–79 period was $46.77, a fall of $4.68 represents an average 10% reduction in value from first-lot to last-lot position.[7]

The hypothesis that quality-corrected prices usually decrease during auctions was further confirmed by similar price regressions in which annually stratified data were included from all Virginia markets during the 1958–79 period. To the extent quality-corrected prices do trend downward, three consequences follow.

First, livestock sellers as a group are at least partially successful in extracting economic rent from livestock buyers, especially during the early part of a sale.

Second, livestock auctions transmit somewhat distorted relative price signals, especially for lots sold near the beginning and end of a sale. For example during 1973–79, Winchester prices for 800-pound choice Angus steers on average were $2.32 per hundredweight lower than for 800-pound choice Charolais steers. But they would have averaged about $5.83 lower in the absence of Angus' superior position in the order of sale. At markets which tend to sell higher-valued animals before lower-valued ones, realized price premiums for the higher-valued animals are generally somewhat greater than can be justified by expected profitability alone.

Third, owners of livestock offered for sale early in an auction tend to receive windfall gains associated with lot position; owners of late-offered livestock suffer corresponding windfall losses.

The existence of a lot position effect on price should be a disincentive for market operators always to order lots according to the same characteristics. However, this disincentive may not outweigh the benefits of predictability and convenience that consistent lot ordering provides to buyers along with the possibility that early offerings of higher quality cattle may raise buyers' quality estimates of cattle offered subsequently. These issues will soon increase in importance because, with the likely advent of electronic auctions, a larger proportion of cattle will be officially graded. This will enhance the opportunity of market operators to order lots according to animal characteristic.

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[7] The average −23.41 was calculated using OLS1 figures, with the ridge estimate of −63.0 replacing the OLS estimate of −97.9 on 11/17/78. A 10% reduction compares closely with a 10.7% estimate derived from Kuehn's aggregate 1976–77 results (p. 8).

Import Substitution for Livestock Feed in the Caribbean Community

Clifton Charles, David Blandford, and Richard N. Boisvert

This paper evaluates the economic feasibility of substituting domestically produced corn and soya for imports in the Caribbean Community. A linear programming model is used to minimize the costs of meeting feed demands under free trade and two self-sufficiency scenarios. Special emphasis is given to the availability of land suitable for feed production, domestic production costs relative to import costs, and the implications for employment and the balance of payments. The model also identifies optimal quotas or tariffs to achieve self-sufficiency.

Key words: customs unions, import substitution, international trade policy, less developed countries, linear programming, livestock feed.

Import substitution is defined as the replacement of imported goods by the same or similar goods produced domestically (Ahmad). It attracted attention initially as a means of promoting industrial development in less developed countries (LDCs). There is now more emphasis on agriculture (Sisler and Blandford), primarily because of the tripling of LDC imports of grain during the 1970s (International Bank for Reconstruction and Development).

Another important trade policy development is the formation of customs unions and free-trade areas to promote trade among LDCs (Baldwin and Kay). Advocates of these arrangements point to traditional benefits of specialization and to the expectation that more "equitable" trading relationships will emerge between nations at similar levels of economic development.

The Caribbean Community (CARICOM), a customs union of twelve Caribbean countries, is a prime example of the coalescence of these two themes in LDC trade policy.[1] Food consumption, particularly meat and other livestock products, has been growing rapidly in CARICOM. As a result, imports of animal feed (corn and soya meal) to support the livestock industry more than quadrupled in value between 1970 and 1978. Such growth has been viewed with concern in CARICOM, both because of its foreign exchange implications and because the Community desires to promote intraregional trade and integration. In response, experimental projects to evaluate the technical feasibility of producing corn and soya, have been established in Belize, Guyana, Jamaica, and Trinidad and Tobago.

This paper evaluates the economic feasibility of substituting domestically produced corn and soya for imports in CARICOM, given the availability of suitable land. The implications for employment, balance of payments, and quotas or tariffs necessary to achieve self-sufficiency are emphasized.

Background

The current balance of payments situation, composition of exports, and the dominance of sugar in agricultural production make import substitution of corn and soya particularly attractive to CARICOM. Because both population and income are concentrated in Barbados, Guyana, Jamaica, and Trinidad and Tobago (the more developed CARICOM countries, MDCCs), the situation in these countries is particularly critical.

For two of the MDCCs, Barbados and

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[1] CARICOM is the successor to the Caribbean Free Trade Association (CARIFTA), formed in 1968. Member countries are Anguilla, Antigua, Barbados, Belize, Dominica, Grenada, Guyana, Jamaica, Montserrat, Nevis, St. Kitts, St. Lucia, St. Vincent, and Trinidad and Tobago. Eight of these countries are small and/or have low per capita incomes relative to Barbados, Guyana, Jamaica, and Trinidad and Tobago.

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Jamaica, import substitution could reduce persistent merchandise trade deficits, which on an annual basis averaged $88 million and $73 million, respectively, during 1970–78. (All prices, costs, and revenues in this paper are in U.S. dollars.) The balance of payments imperative is not so great in Guyana and Trinidad and Tobago. Guyana had a surplus averaging $6 million annually over the period; the surplus in Trinidad and Tobago has been substantial (nearly $200 million per year) because of petroleum exports. However, in all four countries, export earnings are derived primarily from an unstable sugar market or from nonrenewable finite resources (bauxite/alumina or petroleum). Hence, import substitution is attractive to all four MDCCs.

To examine the potential for import substitution of livestock feed, one must understand the current role of sugar. In 1973, the total investment in sugar estates and factories in CARICOM was over $200 million. Sugar cane occupied approximately 500,000 acres of arable land, and both directly and indirectly provided employment for approximately 500,000 persons, or 11% of the population (Girwar). Sugar occupies the largest amount of arable land devoted to any single crop. However, in recent years the high level of trade protection has been important to the survival of the industry. Caribbean exporters benefited from preferential sugar pricing on their exports to Britain under the Commonwealth Sugar Agreement. Since Britain entered the European Community (EC) in 1973, CARICOM has continued to receive preferential treatment, through the Lomé Convention. Because the EC is now a surplus sugar producer, CARICOM's preferences are unlikely to persist indefinitely. McGregor cites two instances in which recent sugar price increases under Lomé have failed to keep pace with increasing production costs in CARICOM. The other important market for Caribbean sugar, the United States, is being threatened by high fructose corn sweeteners and increased competition from other sugar surplus countries.

Although authorities are divided over whether to continue in sugar or replace it with other products, all agree that in order for the sugar industry to survive, drastic structural transformation will be required (Girwar). This opens the way for import substitution of feed grains, to utilize land resources which have been dominated by sugar.

There are two ways in which such import substitution could occur—through either the expansion of currently produced domestic feedstuffs or the development of a corn/soya industry. The potential for increased grass-fed livestock production is strictly limited because of the lack of suitable land. Although root crops, especially cassava, are of great importance as an energy source in livestock feed in Europe, CARICOM's human demand for cassava far exceeds domestic production (Osuji). Copra production is declining, and it is primarily used for oil, little being available for protein meal production.

The greatest potential appears to lie in cane feed, a mixture of chopped cane stalks, leaves, and prescribed supplements. Its cost compares favorably with other commercial feeds (Lambie & Co.). Cane feed's major disadvantage is that it must be served fresh and prepared carefully. It requires the integration of livestock and sugar cane production.

Primary emphasis in the region has been on the development of corn/soya production. Because the livestock industry is already accustomed to using these inputs, direct import substitution implies minimal adjustment in current feeding practices. Corn/soya concentrates are storable and do not have to be fed where they are produced. This flexibility can contribute to both economic and political objectives. A final advantage is the potential for the joint production of soya oil, a valuable product in a region deficient in vegetable oils.

Analytical Framework

An evaluation of import substitution for corn and soya must consider the costs of production, processing, and transportation of feed grains, implications for land and labor use, and the effect upon CARICOM's foreign exchange position. A linear programming model, to determine the optimum allocation of resources and distribution of products within CARICOM, provides the basis for this evaluation. Combined production, import, and transportation costs are minimized under three import substitution scenarios: (*a*) free trade, (*b*) regional self-sufficiency in feed, and (*c*) regional self-sufficiency in vegetable oil. For each, the model generates an optimal allocation of land among corn, soya, and sugar production and the optimal distribution of products within the region.

Mathematically, the model is formulated as follows:

$$(1)\quad \text{Minimize } Z_0 = \sum_{i=1}^{I}\sum_{g=1}^{G}\alpha_{ig}Y_{ig} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{g=1}^{G}c_{ijg}X_{ijg},$$

subject to

$$(2)\quad \sum_{g=1}^{G} Y_{ig} \leq S_i (i = 1, \dots, I);$$

$$(3)\quad -a_{ig}Y_{ig} + \sum_{j=1}^{J} X_{ijg} \leq 0 (i = 1, \dots, I; g = 1, \dots, G);$$

$$(4)\quad \sum_{i=1}^{I} X_{ijg} \geq D_{jg} (j = 1, \dots, J; g = 1, \dots, G);$$

$$X_{ijg} \geq 0;\ Y_{ig} \geq 0 \text{ (for all } i, j, g);$$

where Y_{ig} is acres of commodity g produced at origin i; a_{ig}, output per acre of commodity g at origin i; X_{ijg}, units (tons or gals.) of commodity g transported from origin i to destination j; α_{ig}, the cost/acre of producing commodity g at origin i; c_{ijg}, the transport cost/unit of commodity g from origin i to destination j; S_i, the supply of land at origin i; and D_{jg}, the demand for commodity g at destination j.

Import substitution could have several impacts on the agricultural sector. In the long run, prices and quantities would be affected by changes in trade policy. Nevertheless, costs of production and distribution could be minimized within the constraints imposed by such policy. The cost minimization implicit in the programming model reflects only part of the adjustment likely to take place in the long run. For this analysis, it was necessary to assume that prices (including exchange rates) remain constant, that minimum levels of final demand must be met, and that these levels can be determined exogenously.[2] Given the "small country" characteristics of the region, these are not unrealistic assumptions.

The programming model does generate some information on equilibrium prices for fixed levels of demand. Equilibrium prices are embodied within the dual of the programming problem, which can be expressed as

$$(5)\quad \text{Minimize } Z^* = \sum_{i=1}^{I} S_iL_i - \sum_{j=1}^{J}\sum_{g=1}^{G} D_{jg}Q_{jg},$$

subject to

$$(6)\quad L_i - a_{ig}P_{ig} \geq -\alpha_{ig} \quad (i = 1, \dots, I; g = 1, \dots, G);$$

$$(7)\quad P_{ig} - Q_{jg} \geq -c_{ijg} \quad (i = 1, \dots, I; j = 1, \dots, J; g = 1, \dots, G);$$

$$(8)\quad L_i \geq 0;\ P_{ig} \geq 0;\ \ Q_{jg} \geq 0 \text{ (for all } i, j, g),$$

where L_i is the rent/acre of land; P_{ig}, the value of product g at origin i; Q_{jg}, the value of product g at destination j; and other terms are as defined in equations (1)–(4).

The dual generates implicit values for land and the products at their origins and destinations. The latter are of particular policy interest. As demonstrated by Waverman, minimum preventive tariffs, tariffs that reduce imports from outside the region to zero, can be obtained by comparing the free trade programming solution with a solution in which imports of a particular commodity are prohibited. The difference between the imputed value at a destination, derived from the restricted model, and the imputed price under free trade is equal to the tariff that would reduce imports to zero and achieve complete import substitution.

To specify the model empirically, six subregions were identified. Five are the largest individual countries within CARICOM (the MDCCs plus Belize); the sixth represents CARICOM's international markets (the "rest of the world"). Each of the subregions is both a supply origin and demand destination for one or more agricultural products. In all CARICOM subregions, sugar is a potential production activity. With the exception of Barbados, which is unsuited to feed grain production, double cropping of corn and/or soya is allowed. Soya production costs include costs of processing into oil and meal, implying that processing occurs near the point of production. Feed grain activities in Belize and Guyana include necessary land clearing costs.

The information on input requirements and yields for corn/soya was derived from unpublished experimental farm data (see Charles for details) and from information given in Radley. Costs of production are based on 1975 input prices. For corn production, costs range from $225 per acre in Belize and Trinidad and Tobago to $310 per acre in Jamaica. Soybean production costs range from $200 per acre in

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[2] A strict application of project appraisal techniques to import substitution policy would require that the costs of production and distribution reflect the social opportunity costs of resources (Little and Mirrlees). In developing, labor surplus countries, existing wage rates may not reflect the social opportunity cost of labor. Similarly, the exchange rate may not be an equilibrium rate, implying that domestic resources may be over- or under-valued relative to resources internationally. No attempt is made in this study to assess the difference between money and social costs.

Guyana to $320 per acre in Jamaica. These figures are based on relatively capital-intensive technology and reflect slight differences in machinery complements. More important, they reflect differences in input levels due to soils, rotations, and labor costs.

Yields for corn, for example, ranged from 1.1 (long) tons per acre in Belize and Guyana to 1.8 tons per acre in Trinidad.[3] The costs of producing sugar ranged from $450 per acre in the low rainfall areas of Barbados to almost $880 per acre in peasant holdings of Trinidad. Sugar production costs and yields are derived from information provided by governments or growers' organizations. Further data on costs and yields are given by Charles. Tables containing a summary of the data employed in the model, as well as differential costs between capital and labor intensive technologies, are published in Charles, Blandford, and Boisvert.

The programming model also includes activities for importing corn and soya meal and oil from outside CARICOM and trade among countries within CARICOM. Import prices from outside CARICOM to the four MDCCs are actual 1975 CIF prices. Transport costs for corn/soya between the MDCCs for 1975 are estimated from unpublished data obtained from the West Indies Shipping Corporation.

The constraints in this model differ from those in a conventional transportation programming model. The production of each commodity in each country is determined endogenously and is constrained only by the availability of suitable land. (No constraints on the supply of labor are assumed because CARICOM is a labor surplus area.) Land, which could be devoted to corn/soya production, includes land currently in sugar which is suitable for mechanized feed grain production. This amounts to 47,000 acres in Jamaica and 60,000 acres in Trinidad and Tobago. It also includes 20,000 and 7,500 acres of currently uncleared land in Guyana and Belize, respectively, which are suitable for mechanized feed grain production.

The remaining 343,000 acres included in the model is suitable only for sugar. Additional constraints require that the region meets its domestic demand for corn and soya, defined by 1975 imports. These totaled approximately 210,000 tons of corn, 58,000 tons of soya meal, and 4.4 million gallons of vegetable oil. Two demands for sugar are also identified as separate constraints. A domestic sugar demand in 1975 of roughly 200,000 tons has to be satisfied by domestic production as does an export demand of roughly 625,000 tons. The latter represents the region's 1975 commitments under preferential trade agreements. It is assumed that in the short run CARICOM would be unwilling to jeopardize this assured source of foreign exchange even if sugar prices were relatively low. These commitments reflect an institutional constraint on achieving import substitution in the short run.

The model used 1975 data for two main reasons. First, prior to 1973, the demand for livestock feed never exceeded $15 million (1970 dollars) and, after an increase of 36% between 1973 and 1974, the real value of imports has since appeared to stabilize at around the 1975 level of $22 million. Second, and perhaps more important, this particular year was the only one for which complete information on feed production costs was available. The use of a single year's data is limiting, particularly in its reliance on a single set of import prices.

Empirical Results

In 1975 there was no significant production of feed (corn and soya meal) in any of the five CARICOM countries analyzed. Sugar was produced for export, and all feed demands were met by imports. This actual or "base" situation is the point of departure for analyzing the feasibility of import substitution of feed in CARICOM. The solutions to the programming model provide comparative empirical estimates of feed production, costs, and trade under the three import-substitution scenarios.

Production and Distribution

The major production and distribution patterns for the three scenarios are given in table 1. Because it is assumed that each country will meet its own domestic and preferential export demand for sugar under all scenarios, sugar is omitted from the table. Similarly, Belize is omitted because it neither produces nor imports corn/soya under any scenario.

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[3] Although it could be misleading to use yields derived from experimental trials, the yields actually used in the programming analysis are considerably below the maximum achieved in the region. For example, soybean trials in Trinidad have produced yields in excess of 2,000 pounds per acre. An expected average yield of 1,500 pounds per acre is assumed in the model. Similar downward adjustments were made for corn. Although experiments have suggested that triple cropping may be feasible, only double cropping was incorporated in the model.

Table 1. Production and Distribution of Agricultural Products under Alternative Scenarios

		Destinations			
Origins	Product[a]	Guyana	Trinidad & Tobago	Jamaica	Barbados
Free trade					
Guyana	Corn				
	Soya meal	6,199			
	Soya oil	110,243			236,656
Trinidad & Tobago	Corn	6,188	76,720		11,592
	Soya meal		18,963		1,865
	Soya oil		1,087,428		74,756
Jamaica	Corn				
	Soya meal				
	Soya oil				
Extraregional (rest of world)	Corn			115,357	
	Soya meal			31,357	
	Soya oil	347,246		2,539,642	
Feed self-sufficiency					
Guyana	Corn	6,188			
	Soya meal	6,199		8,997	1,483
	Soya oil	457,489	7,991	155,859	311,412
Trinidad & Tobago	Corn		76,720	49,543	11,592
	Soya meal		18,963		382
	Soya oil		1,079,437		
Jamaica	Corn			65,815	
	Soya meal			22,360	
	Soya oil			1,246,682	
Extraregional (rest of world)	Corn				
	Soya meal				
	Soya oil			1,137,100	
Oil self-sufficiency					
Guyana[b]	Corn				
	Soya meal	19,000			
	Soya oil	457,489		294,299	311,412
Trinidad & Tobago[c]	Corn	6,188	76,720	9,044	11,592
	Soya meal		26,289	6,554	1,865
	Soya oil		1,087,428	849,251	
Jamaica	Corn				
	Soya meal			24,804	
	Soya oil			1,396,093	
Extraregional (rest of world)	Corn			106,313	
	Soya meal				
	Soya oil				

[a] Corn, soya meal, and sugar are measured in long tons, soya oil in imperial gallons.
[b] After CARICOM's demands are met, 12,801 tons of surplus meal are available in Guyana.
[c] After CARICOM's demands are met, 7,326 tons of surplus meal are available in Trinidad and Tobago.

Perhaps the most significant characteristic of the results is that under free trade, feed production occurs in Guyana and Trinidad and Tobago. Guyana satisfies all of its domestic meal requirements, a quarter of its vegetable oil requirements, and two-thirds of the vegetable oil demand in Barbados. Guyana imports the remaining three-quarters of its soya oil from extraregional sources. Trinidad and Tobago meets all of its domestic demand for corn, meal, and vegetable oil, as well as all of Guyana's demand for corn, Barbados' total demand for corn and meal, and a quarter of its demand for vegetable oil. Jamaica continues to import all of its domestic requirements of feed and vegetable oil from extraregional sources.

Under the feed self-sufficiency scenarios, production of corn also occurs in Guyana. The country is able to meet all of its requirements for feed and vegetable oil and export to Barbados, Jamaica, and Trinidad and Tobago.

The most significant change is that Jamaica begins to produce corn and soya even though their costs are high relative to imports. Intraregional trade increases substantially.

Under regional self-sufficiency for feed, vegetable oil production still falls short of demand by over 1 million gallons. In the final scenario, vegetable oil demand is the major constraint of the model. Regional self-sufficiency in oil is obtained, and feed demand is met at minimum cost by importing just over 106,000 tons of corn into Jamaica. Guyana and Jamaica specialize in soya production, while Trinidad and Tobago produces both corn and soya. Regional self-sufficiency in both vegetable oil and feed is not possible given limited land resources and 1975 levels of demand in feed, oil, and sugar.

Resource Use

Land and labor provide the primary focus for discussion because of the scarcity of the former and the lack of employment for the latter. The total cropland incorporated in the model is approximately 477,000 acres. The acreage devoted to corn and soya ranges from 52,000 acres under free trade to 120,000 acres under feed self-sufficiency. This demonstrates the feasibility of satisfying the bulk of the regional demand for feed and vegetable oils, at 1975 levels, with no more than 25% of the region's sugar land. Because the model minimizes the cost of meeting domestic demands and the contractual export demand for sugar, the solutions indicate that some land producing sugar in 1975 is "idled" under all scenarios. The area of idled land ranges from roughly 78,000 acres under free trade to 10,000 acres under feed self-sufficiency.

The most important resource use consequences are for labor. The feed production costs used in the programming analysis correspond to the most capital-intensive technology available (Charles). Total man days per year employed in corn/soya production with this technology is given in table 2. For Jamaica and Trinidad and Tobago, the numbers in parentheses indicate the employment generated if land devoted to corn/soya had remained in sugar production. By subtracting the number in parentheses from the one above it, the net employment effect of import substitution directly attributable to land diverted from sugar production is obtained. Because land used to produce feed in Guyana and Belize was not used for sugar in 1975, there is no opportunity cost of employment associated with import substitution. Therefore, in these countries all employment generated by corn/soya is a net addition.

The demand for labor varies with each scenario and with the product mix. Guyana is the only country where net employment increases in all cases. The results for Trinidad and Tobago and Jamaica present a contrast. Under capital-intensive assumptions, feed production reduces employment in Trinidad and Tobago, but in Jamaica, employment declines only under feed self-sufficiency.

Any reduction in agricultural employment because of import substitution may present problems for these developing nations. For this reason, three additional programming specifications were considered in which the use of labor-intensive feed grain technology was assumed in Trinidad and Tobago and Jamaica. Under this assumption, production costs for feed increase by at least 38%. The major programming results under these assumptions are given in Charles, Blandford, and Boisvert. Although there are several changes in production patterns, the most important can be inferred from the employment summary in table 2. Belize now enters the self-sufficiency scenarios as an exporter to other CARICOM countries. Feed production in Trinidad and Tobago is no longer competitive under free trade. Employment effects in Jamaica and Trinidad and Tobago are significant under self-sufficiency. In both cases, Jamaica has a substantial net increase in employment. Trinidad and Tobago experiences a net reduction of 15% under feed self-sufficiency. These results suggest that labor-intensive technology may be attractive to policy makers. However, since government efforts to date have focused on capital-intensive technology, the remainder of the analysis is based on that assumption.

Trade Policy Instruments

The results of the programming model suggest that under free trade, CARICOM will not be self-sufficient in either feed or vegetable oil. In order to achieve self-sufficiency, new trade policies probably would have to be employed. The policies considered are import quotas and tariffs. Although a production subsidy is the theoretically preferred alternative for achieving import substitution because it avoids the

Table 2. Labor Use in the Production of Corn/Soya

Country	Free Trade	Feed Self-Sufficiency	Oil Self-Sufficiency
	(thousands of man days per year)		
Capital-intensive technology			
Guyana	104	292	320
Trinidad	443	499	636
& Tobago	(1,261)[a]	(1,620)	(1,620)
Jamaica		464	378
		(506)	(283)
Labor-intensive technology			
Guyana	292	292	320
Trinidad	0	1,380	1,795
& Tobago		(1,620)[a]	(1,478)
Jamaica	0	1,220	1,273
		(431)	(273)
Belize	0	83	83

[a] Figures in parentheses denote labor use associated with the previous production of sugar on land diverted to corn/soya.

consumption cost of a tariff or quota (e.g., Corden), it is not considered because of its potential cost to CARICOM countries.

To meet self-sufficiency objectives, only two countries, Guyana and Jamaica, would need to employ import quotas. Under both scenarios, imports of soya oil into Guyana and soya meal into Jamaica would have to be prohibited. Under self-sufficiency in feed, imports of soya oil into Jamaica would be restricted to 45% of their free-trade level (1.14 million gallons). Under self-sufficiency in vegetable oil, imports of corn into Jamaica would be restricted to 92% of their free trade level (106,000 tons).

Superficially, quotas appear to be desirable because of their administrative simplicity, and because they would have to be employed by two only countries. Although not technically illegal for agricultural products under the General Agreement on Tariffs and Trade (GATT), quotas are frowned upon by the international community and could invite retaliation (Meerhaeghe). One clear alternative to quotas is an import tariff.

In order to estimate required tariffs, it is necessary to examine the market prices that would obtain for agricultural products under the various scenarios. Market (shadow) prices are derived from the dual programming problem and are presented in table 3. The programming model guarantees that, where imports from outside the region occur, the shadow prices are equivalent to 1975 import prices. In subregions where shadow prices are below import prices, the imputed value of the resources needed for production is lower than the cost of importing the product. In such a subregion, no trade with countries outside CARICOM will occur.

The shadow prices also indicate how a change in import prices from the rest of the world might affect the feasibility of import substitution. The difference between the 1975 import price and a corresponding shadow price indicates the penalty cost of importing from the rest of the world. Thus, under free trade, the import price of corn in Guyana could fall to 70% of its 1975 level before Guyana would import corn from the rest of the world rather than from Trinidad and Tobago (table 1). Based on the penalty costs, world prices of feed and vegetable oil could fall by 14% to 46% before the feasibility of import substitution could be affected under free trade.

Under the self-sufficiency scenarios, there are instances where shadow prices are above import prices. Imports from outside CARICOM do not occur because they are prohibited in the model's specification. Under these circumstances, the specific tariff needed to prevent all imports of a commodity is calculated by subtracting the import prices from imputed market prices in table 3, if the difference is positive. Waverman suggests that the theoretically minimum preventive tariff is the free-trade-imputed price subtracted from the imputed price under self-sufficiency. However, in this analysis, feed production in CARICOM takes place under the free-trade scenario and intraregional trade is allowed.

Table 3. Import Prices and Imputed (Shadow) Market Prices

	Import Prices '75 (Base Case)	Free Trade	Feed Self-Sufficiency	Oil Self-Sufficiency
	($)[a]			
Guyana				
Corn (70%)[b]	268.65	186.76	195.01	143.11
Soya meal (54%)	381.55	205.72	252.50	0[c]
Soya oil	3.90	3.90	3.07	9.29
Trinidad and Tobago				
Corn (77%)	187.29	143.76	169.80	100.11
Soya meal (60%)	278.99	167.87	259.50	0[c]
Soya oil (85%)	4.66	3.95	3.35	9.34
Jamaica				
Corn	160.11	160.11	229.80	160.11
Soya meal	193.28	193.28	316.50	60.00
Soya oil	3.55	3.55	3.55	9.77
Barbados				
Corn (86%)	210.74	186.76	212.80	143.11
Soya meal (78%)	269.76	210.87	302.50	43.00
Soya oil (74%)	5.69	4.23	3.40	9.62

[a] Corn and soya meal prices are per long ton; soya oil price is per imperial gallon.
[b] Percentages in parentheses denote the ratio of the shadow price under free trade and the corresponding import price.
[c] These zero prices result from there being excess meal produced in the countries.

The 1975 import prices in some countries are therefore greater than the imputed prices derived from the free-trade scenario. Thus, some of the tariffs that would have to be imposed to prevent imports are less than the difference between the imputed prices from the free-trade and self-sufficiency scenarios; they are obtained by subtracting 1975 import prices from corresponding self-sufficiency prices.

In the feed self-sufficiency scenario, specific tariffs are required only on corn and meal in importing countries (table 4). None is required on soya oil because of the joint product nature of oil and meal, which ensures substantial oil production even when meal demand is the limiting factor. Similarly, with self-sufficiency in oil, a tariff is required only on oil. In this case, both the joint product nature of meal and oil, and the crop rotation systems for corn and soya preclude the need for corn and meal tariffs.

Two principal observations can be made about these tariffs. First, as the ad valorem equivalents indicate, five of the eight tariffs are in excess of 50%, and they range as high as 175%. Second, a common market requires the adoption of a common external tariff by member countries. The establishment of a common external tariff at the highest level would increase prices in some member countries above those required to achieve regional self-sufficiency. The increased costs may be politically unacceptable to some member countries and could further alter the patterns of production and distribution within the re-

Table 4. Minimum Preventive Tariffs Assuming 1975 Import Prices

		Self-Sufficiency Scenario	
Country	Product	Feed	Oil
		($ per unit)[a]	
Guyana	Soya oil		5.39 (138%)
Trinidad & Tobago	Soya oil		4.68 (100%)
Jamaica	Corn	69.69 (44%)	
	Soya meal	123.22 (64%)	
	Soya oil		6.22 (175%)
Barbados	Corn	2.06 (1%)	
	Soya meal	32.74 (12%)	
	Soya oil		3.93 (69%)

[a] Corn and soya meal are in long tons; soya oil is in imperial gallons. Numbers in parentheses represent the ad valorem equivalent (percentage of the import price) of the specific tariff.

gion. Because import prices differ among countries the potential for importing via a low-cost country and transshipping to a high-cost country could be created. Even with transshipment, equilibrium prices in some countries would be above those under an optimal differential tariff policy. A more complex programming analysis in which both prices and quantities are determined endogenously would be needed to determine the full implications of this policy.

Foreign Exchange

The effect of import substitution on the balance of payments of CARICOM's member countries is important. The figures given in table 5 reflect the opportunity cost of import substitution in terms of foreign exchange. They include the savings resulting from the reduction in feed and vegetable oil imports from outside CARICOM, valued at 1975 world market (import) prices, and each country's earnings or expenditures resulting from trade in feed and vegetable oil with other CARICOM members.

The values for Trinidad and Tobago and Jamaica incorporate losses in foreign exchange from sugar exports directly displaced by feed production. Expenditures on imports are calculated using the relevant destination price in table 3. Earnings from exports are calculated using prices at their origin. Expenditures on transportation, for both intra- and extraregional trade, are treated as a foreign exchange expenditure (loss), even though some may accrue to flag carriers of the countries concerned. It was not possible to include (net out) any import component of agricultural production and processing costs. This will not affect conclusions drawn from the table unless the import content of sugar production is significantly different from that of feed grains.

Table 5. Change in the Foreign Exchange Position Associated with Import Substitution, 1975

Country	Free Trade	Feed Self-Sufficiency	Oil Self-Sufficiency
	($ millions)[a]		
Guyana	+ 4.3	+10.8	+10.8
Trinidad & Tobago	−29.4	−35.9	−37.1
Jamaica	0.0	−57.8	−37.1
Barbados	+ 0.9	+ 0.6	0.0
CARICOM[b]	−24.2	−82.4	−63.4

[a] The values given in the table for Trinidad and Tobago and Jamaica reflect the foreign exchange opportunity cost of using land previously devoted to export sugar production to produce feed.

[b] Detail may not add due to rounding.

Only two countries, Guyana and Barbados, realize a net foreign exchange saving from import substitution. In Guyana's case, this is because its production of feed and vegetable oil does not displace existing sugar production. It gains by saving on imports from extraregional sources, and also (with the exception of the free-trade case) through a positive net trade balance with other CARICOM countries. In two of the three scenarios, Barbados has an overall net gain, since its expenditure on CARICOM-produced feed and oil is lower than the cost of obtaining these from outside the region. In Trinidad and Tobago, and Jamaica, the loss of foreign exchange from displaced sugar production dominates. Since Trinidad and Tobago is an exporter of feed/oil under all scenarios, its losses are less than those of Jamaica, which is primarily an importer.

Under all scenarios, there is a net loss in foreign exchange from the production of feed/vegetable oil in CARICOM. The loss is smallest under free trade ($24.2 million), but is still significant, primarily because in 1975 the world sugar price was 50% above the average for 1970–78 (International Bank for Reconstruction and Development). Under more moderate sugar prices, the foreign exchange losses from displacing sugar production would be mitigated.

Conclusions

In 1975, the year on which this study is based, corn/soya production in CARICOM was in the early stages of development. Imports of animal feed to satisfy demand from the new, rapidly expanding livestock-feeding industry had been growing, promoting considerable regional interest in the possibility of import substitution. A number of pilot production projects had been established to explore the technical feasibility, reduce the uncertainties of a new agricultural activity, and lower institutional barriers to change. The programming analysis performed in this study is designed to assist in the evaluation of import substitution.

Based on a model designed to minimize the costs of meeting 1975 feed demands, 45% of CARICOM's imports of corn and soya meal and over 30% of its imports of soya oil could be displaced by domestic production under free trade. Jamaica is the only country which continues to import all its corn/soya requirements from outside CARICOM. Land resources within the Community are not adequate to achieve self-sufficiency in both feed and oil. However, self-sufficiency in one or the other is possible.

Self-sufficiency has significant implications for resource use and foreign exchange. For example, feed grain production generates increased employment in Guyana, since undeveloped land is brought into production. When land which was used for sugar in 1975 is diverted into capital intensive corn/soya production in Trinidad and Tobago, employment is reduced. Even if labor-intensive methods were adopted, there would still be a reduction in agricultural employment under feed self-sufficiency.

The foreign exchange implications of import substitution differ significantly among countries. Guyana saves foreign exchange in meeting its soya needs and exhibits a net foreign exchange surplus in its corn/soya trade with other CARICOM countries. In contrast, because corn/soya production in Jamaica displaces sugar for export, Jamaica's overall foreign exchange position deteriorates significantly at 1975 prices.

The trade restrictions needed to achieve self-sufficiency add further complications. Superficially, it appears that quotas, required only in Guyana and Jamaica, provide the simplest means to control imports. However, quotas are not viewed favorably in the international community. Prohibitive tariffs provide a theoretical alternative, but the rates required would generally be over 50% and would differ between member countries. Since CARICOM has been attempting to harmonize its policies and adopt a common external tariff, setting common rates at the highest level may unnecessarily increase the costs of feed in some member countries and could disrupt trade patterns within the Community.

In conclusion, this analysis is a preliminary assessment of the feasibility of import substitution. It is based on the best cost and input information available, and on import prices and feed demands consistent with this information. To forecast the long-term feasibility of import substitution in CARICOM, additional analysis would certainly be required.

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The Demand for Calories in Developing Countries

Odin K. Knudsen and Pasquale L. Scandizzo

This paper employs characteristic demand theory to estimate demand functions for calories for a set of developing countries and to investigate the potential impact of income growth, redistribution, and price changes on alleviating underconsumption of calories. The analysis finds that, although calorie elasticities with respect to income are substantial for the poorer consumers, income growth above historical rates is required for the food needs of the entire population to be satisfied within the next fifteen years, even if calorie prices remain constant and income distribution does not become more unequal.

Key words: calorie consumption, demand theory, economic development, income distribution.

This paper uses household survey data on consumption to analyze the determinants of calorie intakes in developing countries. The paper relies on characteristic demand analysis for a demand function specification for calories. It explores the effect of calorie price differences, income, and other socioeconomic factors on the intracountry and intercountry distribution of calorie intakes. Using the estimated functions, we make broad macroestimates of the potential impact that income growth and redistribution could have on alleviating malnutrition.

The paper reaches three broad conclusions. First, both income and price elasticities of demand for calories are below unity and tend to cluster around 0.60 for the poorer consumers. They are much lower for higher income groups. Second, even a moderate increase in calorie prices implies a large nutritional sacrifice for the poor if present income growth and distribution trends continue. Only a considerable acceleration of economic growth trends would permit calorie needs for the entire population to be satisfied within the next fifteen years. Third, if moderate redistribution policies permit a substantial portion of the income increase to be allocated to the poor, sizable calorie price increases would not rule out elimination of malnutrition. In this case, price increases could generate production increases without ill effects on the nutritional status of the poor.

The Theoretical Model

The recent focus on malnutrition by economists has been through income-group-specific demand analysis. Three approaches have currency. One method used by Pinstrup-Andersen, Londoño, and Hoover is to estimate demand functions for specific commodities by income class using the Frisch method. By assuming want independence among commodities, a matrix of direct price and cross elasticities is derived using estimated income elasticities of demand, budget proportions, and a coefficient for the flexibility of money. This demand matrix is then converted to a matrix of direct and cross-price elasticities for nutrients and used to assess the nutritional status of low income groups under various income and pricing policies. The drawbacks of this method are the extensive data requirements, the crucial role of the separability assumption, and the need to use an estimated coefficient of money flexibility.

A second method by Timmer and Alderman uses Indonesian household data to estimate, for four income groups, calorie elasticities

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with respect to income and rice, cassava, and corn prices. Because calories and quantities are directly linked, this approach corresponds to analysis of commodity demand functions by income class, with the composite commodity estimates being redundant. Although this technique is preferable to the Frisch method, there are problems with cross elasticities between many commodities and other such interactions. It also requires extensive data, often unavailable in developing countries.

The third method, pioneered primarily by Reutlinger and Selowsky, uses a less elaborate scheme in which relationships between a nutritional characteristic, calories, and income levels are made. Using this characteristic demand function along with income distribution data, the nutritional status of the poorest income group can be estimated and projected. Demand functions for individual commodities need not be estimated. This paper uses the characteristic demand function method but differs from the Reutlinger and Selowsky approach by using household data instead of average countrywide data and by estimating a characteristic price elasticity. This allows price effects to be added to the demand estimates and predictions.

Characteristic demand theory as presented by Lancaster assumes that products are consumed because of the utility derived from their characteristics or properties. For food these would include nutrient content, texture, color, taste, etc. Following this approach, the utility of a representative consumer can be expressed as a function of the characteristics of the goods consumed while the budget constraint is stated in terms of commodities:

$$(1) \qquad \max U = U\,(x_1, \ldots x_m),$$

$$(2) \quad \text{subject to } x_i = f_i(q_i, \ldots q_n); \quad i = 1, 2 \ldots m, \text{ and}$$

$$(3) \qquad \sum_{j=1}^{n} p_j q_j - Y = 0.$$

In (1)–(3), U is the utility indicator; $x_i (i = 1, 2, \ldots, m)$, the ith characteristic; q_j the quantity consumed; and p_j the market price of the jth commodity; Y represents the consumers' income; and f_i, the functional relation that links each characteristic to the n goods.

Forming the Lagrangean for the maximization in (1)–(3), after substituting (2) into (1) yields

$$(4) \quad L = U[f_1(q_1 \ldots q_n), \ldots, f_m(q_1 \ldots q_n)] - \lambda\left(\sum_{j=1}^{n} p_j q_j - Y\right).$$

Differentiating with respect to $q_j (j = 1, 2, \ldots, n)$ and equating to 0 yields

$$(5) \qquad \sum_{i=1}^{m} (\partial U/\partial x_i)\,(\partial f_i/\partial q_j) - \lambda p_j = 0,$$

where $j = 1, 2 \ldots n$. Indicating with $\rho_i = (\partial U/\partial x_i)/\lambda$, the shadow price for the ith characteristic, and with $a_{ij} = \dfrac{\partial f_i}{\partial q_j}$, the marginal "yield" of good j in terms of characteristic i, we can rewrite expression (5) as

$$(6) \qquad p_j = \sum_{i=1}^{m} a_{ij} \rho_i,$$

where $j = 1, 2 \ldots n$. Expression (6) states that the market price of each commodity is equal to a weighted linear combination of the prices of its characteristics, the weights being the amounts of each characteristic provided by one additional unit of the commodity.

At a level of income Y and prices p, let a commodity bundle of food $(q_1, q_2, \ldots, q_J)$ be purchased containing only characteristics i = 1 to I. Then from equation (6) total food expenditure $E(Y,\rho)$ will be

$$(7) \qquad E(Y,\rho) = \sum_{j=1}^{J} p_j q_j = \sum_{j=1}^{J} \sum_{i=1}^{I} a_{ij} \rho_i q_j.$$

Because of the technical relationship between characteristics and commodities, $x_i = \sum_{j=1}^{J} a_{ij} q_j$, (7) can be written as

$$(8) \qquad E(Y,\rho) = \sum_{i=1}^{I} x_i \rho_i.$$

Expressing expenditures in terms of the characteristic "energy" measured in kilocalories per day (indicated for simplicity as "calories"), (8) can be rewritten as

$$(9) \qquad P(Y,\ \rho) = \frac{E(Y,\rho)}{x_c(Y,\rho)} = \rho_c + \frac{\sum_{i=c}^{I} \rho_i x_i}{x_c},$$

where $P(Y,\rho)$ denotes the average expenditure per calorie; ρ_c, the implicit price of calories; and $x_c(Y,\rho)$, the amount of calories consumed. Expanding $P(Y,\rho)$ with a truncated Taylor series yields the linear approximation,

$$(10) \qquad P(Y,\rho) = P(Y_o,\rho) + \alpha(Y - Y_o),$$

where $P(Y_o,\rho) = \lim_{Y \to Y_0} P(Y,\rho)$, $Y_o = \min Y$, and $\alpha = \frac{\partial P(Y,\rho)}{\partial Y}$ evaluated at Y_o.

As income goes toward its minimum level, we can expect food expenditure to be devoted more and more to procuring the most fundamental nutrient, calories. Therefore, we can write

$$(11) \quad P(Y_o,\rho) = \lim_{Y \to Y_0} \frac{\sum_{j=1}^{J} P_j q_j}{x_c} = \rho_{co},$$

where ρ_{co} denotes the price of calories in what can be termed a basic bundle. Substituting (11) into (10) and the resulting expression into (9), we finally obtain

$$(12) \quad P(Y,\rho) = \rho_{co} + \alpha(Y - Y_o).$$

In practice, consumers will face the same basic calorie price except for a random factor reflecting differences in information, location, and other factors. Therefore, assuming that Y_o is sufficiently small, we can rewrite (12) for the kth consumer as follows:

$$(13) \quad P(Y_k,\rho_{ck}) = \rho_{ck} + \alpha Y_k = \rho_{co} + \alpha Y_k + u_k,$$

where Y_k indicates the income of the kth sample unit, ρ_{ck} is the basic calorie price, and u_k is a random disturbance having mean zero and constant variance.

Equation (13) says that the average expenditure per calorie can be decomposed into three parts: (*a*) a basic calorie price equal for all consumers, (*b*) a term depending on the consumer's income, and (*c*) a random element. Indicating with hats appropriate estimates of equation (13), we can conclude that

$$(14) \quad \hat{\rho}_{co}(k) = \hat{P}(Y_k) - \hat{\alpha} Y_k = \rho_{co} + u_k$$

is an estimate of the basic price of calories facing the kth consumer. This estimate can be obtained as the residual of the regression through the origin of Y_k against $P(Y_k)$. In turn, this estimate can be used to evaluate the responsiveness of calorie consumption to variations in its own price.

Estimates of Calorie Demand Functions

The method for estimating the calorie demand function is summarized in three steps. First, we calculate calorie consumption by expenditure groups using data from household consumption surveys (expenditure is used as a proxy for disposable income). For each country in the study, the average quantity of the various food items consumed by households in each expenditure group is converted to calorie levels using FAO calorie consumption tables. Second, we estimate a weighted regression relating the average expenditure per calorie to per capita total expenditure. We then use the sum of the constant term and the residuals as an estimate of the basic price of calories. Third, we estimate a series of functions relating calorie intake to total expenditure levels and to the basic price estimate. We use weighted least squares because sample sizes are different in each expenditure class. The ratios between sample and population sizes (sample "shares") are used as weights.

Because our information consists of income class data for six different countries, all regressions are also subject to the test that (*a*) the coefficient of any variable and (*b*) the value of the constant are significantly different from one country to the other. Furthermore, we test for the effect of five country-specific characteristics: food production per capita, urbanization rate, literacy rate, population size, and adult population to total population ratio.

Table 1 presents the estimates for the average basic prices of calories for each country, computed according to expression (14) and to the estimated cross-country regression between average per capita expenditure per 1,000 calories (converted in U.S. currency at parity exchange rates) and per capita total expenditure. The basic prices vary from 7¢ to 24¢ per 1,000 calories at the parity exchange rate and from roughly 3¢ to 12¢ at official rates. In both cases there is no apparent correlation between the estimated basic prices and the selected socioeconomic characteristics (i.e., food production per capita, urbanization rate, literacy rate, population size and adult ratio).

Table 2 presents selected estimates of calorie demand functions based on the cross-section sample. The functional form is semilogarithmic, a useful form because of the implied inverse relationship between absolute elasticities, income, and prices. For the estimated functions, the basic price indices estimated according to equation (14) are used as price variables. The per capita expenditures (in national currency) are used as income

Table 1. Estimated Average Basic Prices of 1,000 Calories

Country	Currency	In Domestic Currency[a]	Parity Exchange Rate[b]	Official Exchange Rate[c]
Bangladesh	(Takas)	0.48	11.9	6.0
India	(Rupees)	0.54	18.9	6.8
Indonesia	(Rupiah)	51.00	23.2	12.3
Morocco	(Dirhams)	0.50	23.9	9.9
Pakistan	(Rupees)	0.22	6.9	2.8
Sri Lanka	(Rupees)	0.56	14.4	5.6

[a] Units: Domestic currency/1,000 calories.

[b] Units: U.S. ¢/1,000 calories at parity exchange rates as estimated by Kravis, Heston, and Summers.

[c] Units: U.S. ¢/1,000 calories at official exchange rates. The estimated equation used for the above estimates is

$$\underset{(20.6)}{P_c = 23.5} + \underset{(6.8)}{0.85\ Y} + 0.129\ (Y \cdot D_1) - \underset{(-3.1)}{0.029\ (Y \cdot D_4)} + -\ \underset{(-4.5)}{101.\ D_1} - \underset{(-9.7)}{16.2\ D_5} - \underset{(-5.2)}{8.9\ D_6},$$

where $R^2 = 0.95$; P_c is per capita food expenditure in U.S. ¢/1,000 calories; Y is expenditure/capita/month (US$ at parity exchange rate); and D_1 is dummy variables for Bangladesh, D_4 is Morocco, D_5 is Pakistan, D_6 is Sri Lanka (t-ratios are in parentheses).

variables. Separate functions are also estimated for people below and above the calorie-poverty line which is defined as the expenditure level just sufficient to purchase the FAO calorie requirement.

Regressions (1)–(3) in table 2 show that the income coefficients for Bangladesh and Pakistan and the price coefficients for Bangladesh, India, Morocco, and Sri Lanka are not significantly different from each other. Furthermore, factors other than incomes and prices appear to affect calorie consumption across countries. This is indicated by the significant dummy variable coefficients on the intercept and by the significance of per capita food production in explaining residual cross-country differences.

Consider regressions (4)–(6) and (7)–(9) in table 2 and the elasticities shown in table 3. They indicate that calorie response to increases in income at the poverty line varies from a maximum of 0.56 for Morocco to a minimum of 0.18 for Sri Lanka. This indicates that individuals consuming just at the level of the FAO calorie requirement will increase calorie intake between 2% and 6% for every 10% rise in income, if the calorie price is constant. Moreover, the countries with the most malnutrition—Bangladesh, India, Indonesia—all show considerably higher income elas-

Table 2. Calorie Demand Functions across Country and Expenditure Classes

Dependent Variable	Constant	LN(Y)	India LN(Y)* D_1	Indonesia LN(Y)* D_2	Pakistan LN(Y)* D_3	Morocco LN(Y)* D_4	Sri Lanka LN(Y)* D_5	LN(IP)	India LN(IP)* D_1	Indonesia LN(IP)* D_2
Overall caloric intake										
1. Calories/capita/day	−5,180.7	664.9	362.7	217.5	−90.1	583.6	−238.2	−1,072.5	1,077.2	1,105.4
		(6.6)	(1.7)	(2.1)	(−0.5)	(4.1)	(−1.4)	(−3.3)	(1.0)	(3.2)
2. Calories/capita/day	−5,211.9	698.7	139.9	183.8		582.0	−345.5	−1,024.1		1,056.9
		(9.0)	(5.0)	(2.2)		(4.7)	(−2.2)	(−4.0)		(3.6)
3. Calories/capita/day	−18,340.5	651.8	293.5	222.8	150.5	535.0	−251.0	−852.0	1,750.1	927.4
		(5.2)	(1.2)	(1.7)	(0.7)	(3.0)	(−1.2)	(−2.25)	(2.3)	(2.4)
Low calorie intake —below CR										
4. Calories/capita/day Below CR	−6,711.3	702.6	208.6	454.9	567.0	429.4		−1,495.7	1,717.9	343.4
		(3.1)	(0.9)	(2.0)	(1.8)	(1.9)		(−2.4)	(2.3)	(0.5)
5. Calories/capita/day Below CR	−6,262.0	968.9		101.3	48.7	90.5		−919.6	1,271.5	
		(68.2)		(4.4)	(7.1)	(17.3)		(−19.3)	(2.1)	
6. Calories/capita/day Below CR	−4,564.2	899.6		188.4	172.6	234.8		−970.6	−431.3	
		(22.0)		(2.7)	(3.2)	(4.2)		(−10.5)	(−1.9)	
High calorie intake —above CR										
7. Calories/capita/day Above CR	−3,412.7	534.4	53.1	345.1	33.3	473.0	−107.6	−772.8	1,635.6	660.9
		(2.1)	(1.0)	(1.3)	(0.1)	(1.3)	(−0.3)	(−1.3)	(.04)	(1.3)
8. Calories/capita/day Above CR	−932.1	415.6	78.6	403.2		778.1		−261.0		
		(3.9)	(2.2)	(3.0)		(2.7)		(2.6)		
9. Calories/capita/day Above CR	−1,404.7	467.3	63.1	357.7		731.2		−222.1		
		(3.7)	(1.0)	(2.5)		(2.4)		(−1.4)		

Table 2. (Continued)

Dependent Variable	Pakistan LN(IP)* D_3	Morocco LN(IP)* D_4	Sri Lanka LN(IP)* D_5	India D_1	Indonesia D_2	Pakistan D_3	Morocco D_4	Sri Lanka D_5	Food Production /Capita	Urbanization Rate	R^2	No. of Observations
Overall caloric intake												
1. Calories/capita/day	898.7	−509.0	1,868.4	1,901.5	2,512.8	3,823.9	−3,768.6	7,528.7			0.99	60
	(2.4)	(−0.9)	(1.7)	(0.5)	(2.3)	(3.2)	(−2.3)	(2.3)				
2 Calories/capita/day	931.2				2,544.0	3,564.0	−2,456.0	2,285.4			0.99	60
	(332)				(2.7)	(3.5)	(3.4)	(2.6)				
3. Calories/capita/day	514.9	822.4	−1,370.2						84.1	−7,470.2	0.98	60
	(1.15)	(1.3)	(−2.2)						(2.1)	(−0.9)		
Low calorie intake —below CR												
4. Calories/capita/day	−58.3	530.0		4,619.7	−631.0	−3,152.2	−59.2				0.99	23
Below CR	(−0.1)	(0.8)		(3.2)	(−0.7)	(−1.0)	(−0.1)					
5. Calories/capita/day				4,273.3							0.99	23
Below CR				(2.5)								
6. Calories/capita/day									−7.0	−2,725.5	0.99	23
Below CR									(−.6)	(−1.9)		
High calorie intake —above CR												
7. Calories/capita/day	592.4	−961.1	1,568.7	−232	995.1	2,064.4	−4,372.1	5,760.7			0.99	37
Above CR	(0.9)	(−1.1)	(1.02)	(0.0)	(0.3)	(0.6)	(−1.1)	(1.1)				
8. Calories/capita/day				−2,080.4			−4,120.4				0.98	37
Above CR				(−2.6)			(−2.2)					
9. Calories/capita/day				−1,868.1			−4,041.4		0.63	1,077.2	0.98	37
Above CR				(−2.2)			(−2.2)		(.01)	(1.1)		

Note: Where LN(Y) is logarithmn of expenditures per capita converted to U.S. $ at parity exchange rates: LN(IP)*, logarithmn of the implicit price of calories converted to U.S. $ at parity exchange rates; D_1, dummy variable for India; D_2, dummy variable for Indonesia; D_3, dummy variable for Pakistan; D_4, dummy variable for Morocco; D_5, dummy variable for Sri Lanka; CR, FAO caloric requirement; and t, statistics in parentheses.

ticities and, hence, higher calorie response as income increases. The poorest 25% in these countries have calorie income elasticities between 0.61 and 0.74, indicating that a 10% rise in income will increase calorie intakes by 6% to 7% for the poorest group.

The calorie responses to price increase also show a similar pattern. The poorest 25% of the population from all countries show an average 4.5% to 8.8% fall in consumption in response to an increase of 10% in the calorie price. As for the top 25% of the income distribution, it appears that price responsiveness decreases more than income responsiveness as income increases. A 10% increase in price would cause consumption to fall about 1%, while a 10% increase in income would cause consumption to raise by amounts varying between 1.6% and 3.3%. Therefore, consumers with a calorie intake above FAO requirements exhibit price elasticities of demand that are low with respect to a calorie price relevant to the lowest basis of consumption. This is to be expected as the consumption bundle for these consumers is composed of different and higher quality types of food than for the lower income consumers. The fact that the elasticity is not zero, however, suggests that the low income

Table 3. Calorie Income and Price Elasticities

	Calorie Income Elasticity			Calorie Price Elasticity		
Country	At the Poverty[a] Line	Lowest Quartile[b]	Highest Quartile[c]	At the Poverty[a] Line	Lowest Quartile[b]	Highest Quartile[c]
Bangladesh	0.35	0.67	0.17	−0.51	−0.63	−0.11
India	0.44	0.61	0.16	−0.54	−0.88[d]	−0.09
Indonesia	0.39	0.74	0.28	−0.51[d]	−0.63	−0.09
Morocco	0.56	0.69	0.33	−0.45	−0.60	−0.07
Pakistan	0.34	0.53	0.18	−0.47[d]	−0.48	−0.10
Sri Lanka	0.18	0.17[a]	0.17	−0.51	−0.45	−0.11

[a] Computed from regression 2, table 2.
[b] Computed from regression 5, table 2.
[c] Computed from regression 8, table 2.
[d] Computed from regression 6, table 2.

Table 4. Distribution of Calorie Intake

	FAO/WHO-Recommended Per Capita Calorie Intake[a]	Percentage of Population Consuming below:					
		2,400 Calories	2,200 Calories	2,000 Calories	1,800 Calories	1,600 Calories	1,400 Calories
Bangladesh	2,020	91	75	55	35	18	8
India	1,910	60	48	35	22	12	5
Indonesia	1,920	74	64	53	41	26	12
Morocco	2,276	48	39	30	21	13	7
Pakistan	2,050	97	90	44	2	0	0
Sri Lanka	2,000	84	41	7	0	0	0

[a] Adjusted to account for individual variability.

bundle (the "basic" bundle) is also consumed, although in different proportions and jointly with other goods, by the higher income group.

Implications of the Estimates

These estimates can serve two interrelated purposes. First, they can be used to derive estimates of the calorie intake distribution and related measures of malnutrition directly from income distribution data. Second, they can be utilized to explore the ability for income growth, redistribution and price adjustment to alleviate underconsumption. The estimates obtainable from income distribution statistics have two basic components: (*a*) the percentage of households consuming below the recommended nutritional standard and (*b*) the size of the nutrient deficit by income group. Table 4 contains estimates of the first of these two components for the case of calorie consumption.

A second, possibly more significant, measure of the extent of malnutrition is the nutrition gap, which is the aggregate difference between food (calorie) availability to the households and their calorie requirements (table 5). This measures focuses on the overall nutritional deficit of a country and can be related to (*a*) the size of its undernourished population, (*b*) market demand, and (*c*) the amount of total food needs (i.e., market demand plus the nutrition gap).

Given these estimates, we can investigate the prospects of alleviating malnutrition by closing much of the nutritional gap by 1995. We conduct this analysis under four scenarios: (*a*) constant income distribution and constant calorie prices, (*b*) "optimal" income distribution (defined below) and constant calorie prices, (*c*) constant income distribution and calorie prices increasing at 1% per annum, and (*d*) "optimum" income distribution and calorie prices increasing at 1% per annum.

Under the "optimal" income redistribution scenario, the income of each group with average calorie consumption below the recommended intake is allowed to grow at the rate necessary to close the nutritional gap. The per-capita incomes of the other groups are assumed to grow at 1% per annum. The resulting

Table 5. Nutrition Gaps (Grain Equivalents)

		Total Gap	Average Per Capita Gap Per Year[a]	Proportion of Nutritional Gap to: Market Demand	Total Food Needs
		(millions metric tons)	(kg)	-------(%)------	
Bangladesh	(1974)	2.65	46	16.9	14.4
India	(1974)	9.43	39	6.8	6.3
Indonesia	(1970)	3.75	47	13.2	11.7
Pakistan	(1971)	1.56	66	11.5	10.1
Morocco	(1971)	0.50	26	12.4	11.0
Sri Lanka	(1970)	0.06	16	2.1	2.1

Note: Grain equivalents are converted at 3.5 million calories per metric ton.
[a] Population below the recommended calorie intake.

Table 6. Per Capita Income Growth Rates Necessary to Close the Nutritional Gap by 1995 with Rising Calorie Prices

		Average Growth Rates Required to Close the Nutritional Gap[a]			
		Constant Income Distribution		Optimal Redistribution[b]	
Country	Historical Growth Rate 1960–76	Constant Prices	Calorie Price Increase 1%	Constant Prices	Calorie Price Increase 1%
Bangladesh	−0.4	3.9	4.4	1.24	1.55
India	1.3	2.7	4.3	1.09	1.27
Indonesia	3.4	3.2	4.1	1.09	1.23
Morocco	2.1	4.0	5.0	1.20	1.36
Pakistan	3.1	1.6	1.6	1.00	1.15
Sri Lanka	2.0			1.00	1.00

Note: Based upon regression 4 in table 5 except for Sri Lanka, which used regression 8 and India, which used regression 5.

[a] These are the growth rates necessary to bring the mean consumption of the bottom 10% of the populations up to the FAO/WHO recommended calories intake, adjusted for individual variability.

[b] Those groups with consumption below the adjusted FAO/WHO recommended caloric intake receive an income growth rate necessary to close their nutritional gap; those consuming above the recommended intake are given a 1% growth rate.

average growth rates in per capita income can then be interpreted as minimum growth rates necessary to close the gap assuming a reasonable redistribution of incremental income.

As shown in table 6, the per capita growth rates necessary to close the nutritional gap without a change in income distribution vary from 1.6% to 5% with constant calorie prices. These rates appear rather high and unlikely to be achieved, especially for Bangladesh and India and when calorie prices are permitted to increase.

If we assume an "optimal" redistribution of growth, however, the necessary growth rates decline to about 1.0–1.6% per annum, even with sizable price increase. Thus, if income growth were focused on the poor, malnutrition could be eliminated with modest aggregate growth even with a concomitant rise in calorie prices. This growth would be well within historical rates.

Conclusions

This paper has focused on the determinants of calorie intakes for an important sample of developing countries. Using aggregate data from household budget surveys, the paper has shown that neither foreseeable price increases nor a slackening in economic growth would hamper improvement in the nutritional status of the population if the bulk of the additional income growth is channeled to the poor.

This conclusion, however, also holds in reverse. If the poor's participation in economic growth is less than the rest of the population, their nutritional status is likely to suffer proportionally more. Thus, policies are needed to ensure (*a*) that the undernourished are not excluded from the general improvement in living standards, and (*b*) that they are specifically helped to achieve minimum consumption standards if the process of growth slackens or if income distribution deteriorates.

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Choice of Varieties by Sri Lanka Rice Farmers: Comparing Alternative Decision Models

H. M. G. Herath, J. B. Hardaker, and J. R. Anderson

Sri Lanka rice farmers are faced with a choice between traditional and high-yielding rice varieties. Three risky-choice models are compared to explain producer behavior. Forty farmers with typically small rice areas were studied. Choice criteria compared were multiple (two)-attribute utility maximization, single (profit)-attribute utility maximization, and expected profit maximization. Expected utility maximization performed better than expected profit maximization; single-attribute utility maximization outperformed the more complex multiattribute utility model. The importance of careful elicitation of subjective probability distributions is emphasized. Rice farmers appear to allocate their land between available technologies in an economically rational way.

Key words: modern varieties, multiattribute utility, rice, risk, Sri Lanka, traditional varieties.

An understanding of the decision processes of farmers in developing countries is useful for designing policies to influence their behavior. Many studies testing economic rationality of resource allocation decisions by peasant farmers use Cobb-Douglas production functions fitted to cross-section data (e.g., Hopper, Yotopoulos). Such studies generally show that, within the technological and institutional constraints they face, farmers in developing countries appear to act as profit maximizers. However, these analyses are not very useful in explaining observed individual deviations from computed optimal levels of factor use (Rao, Ohkawa) or in understanding the time-dependent nature of the diffusion of profitable agricultural innovations (Mansfield).

A major criticism of the conventional production theory concerns its omission of risk and risk aversion (Dillon and Anderson, Wolgin). In addition, decisions by peasant farmers appear usually to involve multiple, competing objectives. Recent developments in decision theory have opened the door to more complete analysis of peasant decision making, by incorporating both risk and multiple objectives. Although developed primarily for prescriptive purposes, decision theory can be given a behavioral interpretation (O'Mara). The empirical question of how well the theory predicts the behavior of peasant farmers is addressed in this paper.

The objective of the study is to compare some alternative models of risky choice to explain producers' actual behavior. The approach used involves comparison of actual and predicted farm resource use employing three decision criteria: multiple-attribute utility maximization (MAUM), single-attribute utility maximization (SAUM), and expected profit maximization (EPM).

Methods

If $\mathbf{x} = (x_1, \ldots, x_m)$ is the vector of activity levels reflecting the allocation of resources among alternative uses, the decision problem a farmer faces is to select the best value of $\mathbf{x}$. To analyze this decision problem using multiattribute utility theory, a set of attributes, or measures of effectiveness, $\mathbf{y} = (y_1, \ldots, y_n)$, is defined, describing the extent to which n-prescribed objectives are met by any allocation decision. Well-accepted axioms of rational choice (Anderson, Dillon, Hardaker;

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Raiffa) imply that a decision maker should select $\mathbf{x}$ to maximize his expected utility, given by

$$(1) \qquad EU = \int_y u(\mathbf{y}) f(\mathbf{y}) d\mathbf{y},$$

where u is the decision maker's utility function and f is his subjective probability density function for $\mathbf{y}$ given $\mathbf{x}$.

For single-attribute utility analysis, the measures of effectiveness must be reduced to a single dimension, perhaps by aggregating attributes or perhaps by ignoring some. Then (1) still applies with u and f defined as one-dimension functions only. In general, $\mathbf{y}$ is a vector, but the most frequently analyzed case is when it is a scalar (i.e., a single attribute). A special single-attribute case arises when u is linear and $u(y) = y$, when maximization of the expected value of the scalar y is equivalent to maximization of the expected utility of y.

The Allocation Decision Studied

This analysis relates to the choice, by rice farmers in Sri Lanka, between traditional and modern, high-yielding varieties of rice. The study was conducted in two villages, one in the wet zone in the Kandy district and the other in the dry zone in the Polonnaruwa district. Farmers in both villages generally grow both a modern variety (MV) and a traditional variety (TV). The farms studied were all small—less than two hectares. Moreover, labor inputs per unit of land for MVs and TVs were similar, while nonfarm inputs for rice production (especially for MVs) were available on credit. Consequently, land can be regarded as the principal constraint. Hence, the choice between the two varieties can be represented as

$$(2) \qquad \underset{\mathbf{x}}{\text{maximize}}\ EU = \int_y u(\mathbf{y}) f(\mathbf{y}) d\mathbf{y},$$

$$(3) \qquad \text{where} \qquad \mathbf{y} = y(\mathbf{x}),$$

$$(4) \qquad \text{and subject to } x_1 + x_2 = 1,$$

where x_1 is the proportion of land allocated to the MV and x_2 is the proportion allocated to the TV. In general, $\mathbf{y}$ is a vector of attributes.

Attributes and Objectives

Farmers in the two villages appeared to identify two main goals in rice production—subsistence rice consumption and net cash income. Subsistence consumption, denoted by y_1, was defined as the amount of home-produced rice consumed in a year. Net cash income, denoted by y_2, was defined as cash income from sale of rice less production costs.

These two attributes were also considered in combined form by valuing subsistence consumption at the market price of rice. The rice-marketing system in Sri Lanka is sufficiently well-developed for this to be reasonable. The sum of subsistence and cash income less production costs represents net income used for analysis of single-attribute utility functions and expected profit maximization.

Probability Distributions

The probability distributions used related solely to the yields of the two varieties. This was done partly for simplicity and also because it captures the majority of the risk faced by farmers. For example, the price of rice is fixed by government and known in advance by farmers.

The elicitation of yield distributions was sought from survey respondents relying on a minimum of subjective information. First, marginal distributions for the two varieties were elicited from each farmer. If these distributions were found to be approximately normal, then the joint distribution was treated as bivariate normal. Otherwise, transformations of skewed distributions were made so that bivariate normal distributions could be used for the transformed variables. The bivariate normal was chosen for its ease of elicitation and for the ease with which pseudo-random, correlated deviates can be generated. Some justification for use of the normal distribution when the actual distribution departs from normality is that a Taylor series expansion of expected utility, terminated at the second moment terms, gives a reasonably close approximation. In the few cases where the elicited distributions were markedly skewed, a mathematical transformation was used to make them symmetrical before the normal approximation was applied. This transformation is described below.

The normality assumption permits a relatively simple specification of the joint distribution using marginal and conditional means and variances (Raiffa and Schlaifer, p. 250). In the bivariate case applied here, each complete distribution was specified from the two marginal means and variances and one conditional mean and variance. This information was sufficient for the correlation coefficient, ρ_{12}, to be estimated using the following conditional distribution formulas:

$$(5)\quad E(q_1|q_2 = q_2^*) = \mu_1 + (q_2^* - \mu_2)\rho_{12}\sigma_1/\sigma_2,$$

$$(6)\quad V(q_1|q_2 = q_2^*) = \sigma_1^2(1 - \rho_{12}^2).$$

For the same elicited parameters, three estimates of ρ_{12} can be derived from (5) and (6). These generally differed. Such differences were resolved by first discarding any values outside the range -1.0 $+1.0$. Negative estimates were discarded on the grounds that high positive correlation of yields could be expected. If two positive estimates lay in the range 0 to $+1.0$, the one calculated from equation (5) was selected on the presumption that means were probably more reliably estimated than variances (Anderson, p. 567).

Structure of the Utility Functions

Keeney (1971) has shown how the assessment of multiattribute utility functions can be simplified if utility independence prevails. Attribute y_i is utility independent of other attributes $\bar{y}_i$ if preferences for lotteries involving y_i with $\bar{y}_i$ held fixed do not depend on $\bar{y}_i$. If y_i is utility independent of $\bar{y}_i$ and vice versa, the attributes are said to be mutually independent.

If all attributes are mutually independent, Keeney and Raiffa (p. 238) have shown that the multiattribute utility function can be treated as either additive,

$$(7)\quad u(y_1, \ldots, y_n) = \sum_{i=1}^{n} k_i u_i(y_i),$$

or multiplicative,

$$(8)\quad 1 + Ku(y_1, \ldots, y_n) = \prod_{i=1}^{n} [1 + Kk_i u_i(y_i)],$$

where u and u_i are utility functions scaled from zero to one, the k_i and K values being scaling constants with $0 < k_i < 1$ and $K > -1$ (see also Keeney 1973). If u is additive, $\Sigma_i k_i = 1$, and if multiplicative, $\Sigma_i k_i \neq 1$.

Collection of Data

Two random samples of forty farmers were selected, one from the wet zone village in the Kandy district and one from the dry zone, Polonnaruwa district village. The sampled farmers were interviewed to elicit the required information on subjective probabilities and utilities. However, complete data were obtained from only seventeen farmers in the wet zone sample and twenty-three in the dry zone sample. The results reported below relate only to these farmers.

The low response rates may be attributed, at least partly, to unfamiliarity of both the interviewer and farmers with the concepts and procedures used. While there was no evidence of important differences between respondents and nonrespondents in socioeconomic characteristics, some differences are likely to exist, if only in ability to answer abstract questions. Hence, some indeterminate bias is probably associated with these low response rates.

Assessment of Probabilities

Subjective probability distributions were elicited from each farmer concerning the yields of the two variables grown. Using a visual elicitation method (Anderson, Dillon, Hardaker, p. 22), the interviewer obtained two marginal distributions and one conditional distribution.

The elicited distributions were first checked for normality using a Kolmogorov test. Most were found not to depart from normal at the 10% level of significance. The three that were not normal were made symmetric and, thus, approximately normal using the following power transformation described by Litchfield, Hansen, and Beck:

$$(9)\quad z = (q^w - 1)/w,\ w \neq 0,$$

where z is the transformed value of yield q, and w is the transformation parameter. The parameter w was varied over a reasonable range to find that value which made each distribution approximately symmetric. The test for symmetry was made using the statistic,

$$(10)\quad T = (z_{(\alpha)} + z_{(1-\alpha)})/2z_{(0.5)},\ 0 < \alpha < 1,$$

where the subscripts indicated selected cumulative probabilities (e.g., $\alpha = 0.25$) and $T = 1$ for symmetry (Litchfield, Hansen, Beck).

The elicited distributions, transformed if necessary, were summarized in the form of cumulative functions plotted on normal probability paper. The means and variances required to compute correlation coefficients from equations (5) and (6) were read from these graphs.

The net income distributions required for the single-attribute utility and expected profit analyses were obtained from the elicited yield distributions using a linear transformation to account for (the assumed certain) price of rice and production costs (Herath, pp. 94–96).

Utility Function Elicitation

If mutual utility independence prevails, an additive or multiplicative utility function, such as (7) or (8), can be used in the two-attribute case. In theory, an infinite number of preference comparisons must be made to verify complete utility independence. Because the interviewed farmers had limited ability to respond to questions about their preferences, we assumed that the requirements for mutual utility independence were approximately fulfilled.

The assumption of utility independence was supported to some extent because most surveyed farmers said that their preferences for subsistence consumption would not be affected by changes in cash income. This test was by no means conclusive, but the observed behavior of semi-subsistence farmers suggests that the assumption is reasonable (Herath, pp. 100–101).

The single-attribute utility functions were obtained using the equally likely, certainty equivalent method (Anderson, Dillon, Hardaker, pp. 70–75). After some trials with other algebraic forms, we found that the elicited curves usually could be well-approximated by negative exponential functions. These functions were fitted using the method described by Buccola and French. The negative exponential, which implies constant absolute risk aversion (Pratt), also has been used in previous multiattribute utility studies (e.g., Keeney 1977).

The scaling constants required for (7) and (8) were assessed with a lottery technique. For example, to assess k_1, the scaling constant for utility of subsistence consumption—$u_1(y_1)$, each farmer was asked to consider a situation where y_1 was at the best level possible and y_2 was at the worst. This scenario was compared with one with a probability p of obtaining both attributes at their best levels and a probability $(1 - p)$ of obtaining them both at their worst. The probability was varied until the farmer was indifferent between the two options. Recall that $u_1(y_1)$ and $u_2(y_2)$ are scaled from zero to one. At indifference, $k_1 = p$ (Anderson, Dillon, Hardaker, pp. 82–83). A similar procedure was used for k_2. In all cases, we found that $k_1 + k_2 \neq 1$, so the multiplicative form of equation (8) applied.

The elicited, single-attribute functions for net cash income used to construct the multiattribute functions also were assumed to apply to the single-attribute case with net income as the argument, including both cash and subsistence components. This procedure is reasonable because of constant absolute risk aversion implied by the negative exponential functions.

Optimization

Optimal portfolios of varieties for each farmer were calculated using a Monte-Carlo computer budgeting method. The proportion of land committed to the MV, x_1, was varied between 0 and 1.0 in increments of 0.1. For each farmer's values of x_1, expected utility was estimated by making repeated calculations based on pseudo-random sampling from that farmer's bivariate yield distribution for the two varieties. The approximately optimal value of x_1 was then found by inspection of the computed expected utilities.

Upper and lower bounds to the variations in net incomes and yields were set by truncating the distributions at three standard deviations above and below the means. Outcomes involving negative yields were treated as inadmissible.

For SAUM, the following sequence was employed. For each value of x_1, sampled levels of net income per hectare of each variety were obtained as correlated random drawings from the respective truncated bivariate normal distribution. If required, the transformation correcting for skewness was reversed. Then total net income, y, was found as

$$(11) \qquad y = [x_1r_1 + (1 - x_1)r_2]L,$$

where r_1 and r_2 are the sampled unit net incomes for the MV and the TV, respectively, and L is rice area. The utility of this income level was then found by substitution into an appropriate utility function of the form,

$$(12) \qquad u = \lambda[1 - \exp(cy)],$$

where λ is a constant and c is the individual's risk aversion coefficient. Finally, the process was repeated 1,500 times, and expected utility for each value of x_1 was computed as the sample average.[1]

In the case of EPM, a Monte-Carlo evaluation was not used since the implied indifference to risk makes optimization the simple allocation of total rice area of each farm to the variety having the highest expected income.

The Monte-Carlo evaluation was modified slightly for MAUM. Sampled yields of the two varieties were obtained from the bivariate distributions as were net incomes per hectare in the SAUM case. Total rice production, Q, was then calculated as

$$Q = [x_1q_1 + (1 - x_1)q_2]L, \tag{13}$$

where q_1 and q_2 are the sampled yields of the MV and the TV, respectively. To maximize utility, this total production was then allocated between subsistence consumption and sales according to the following equation derived from (8):

$$u = \{[1 + Kk_1u_1(y_1)][1 + Kk_2u_2(y_2)] - 1\}/K, \tag{14}$$

where subscripts 1 and 2 here apply to subsistence consumption and net cash income, respectively. Since

$$y_2 = (Q - y_1)p - t, \tag{15}$$

where p is price of rice (the same for all varieties) and t is total cost of production, equation (14) can be written as

$$u = ([1 + Kk_1u_1(y_1)] \{1 + Kk_2u_2[(Q - y_1)p - t]\} - 1)/K. \tag{16}$$

The optimal allocation of total production between consumption and sale can be found by maximizing (16) with respect to y_1 for each sampled value of Q. Maximization was performed using the Newton-Rhapson method (Hartree) to find optimal values of y_1 and u. As with SAUM, the evaluation was repeated 1,500 times for each value of x_1 to permit the expected utilities to be calculated. The optimal value of x_1 was found by inspection.

Comparison of the Three Decision Criteria

The purpose of the study was to compare the three choice criteria, MAUM, SAUM, and EPM, in predicting allocations of land between the two varieties. The results are first reviewed in general terms, and then a measure of prediction closeness is provided.

Review of Results

The performance of the three choice criteria in predicting actual behavior of farmers in the two samples is summarized in table 1. The comparisons were made between actual and predicted values of x_1, with predicted values measured in increments of 0.10, and actual values accurate to two decimal places. Thus, cases of exact prediction, discussed below, indicate instances where actual and predicted values of x_1 were identical to two decimal places. For ten of the seventeen farmers in the wet zone, Kandy sample, all three criteria predicted the same land allocation, and in eight of these cases predicted values were identical to actual (table 1).

The results for the remaining seven farmers in the Kandy sample for whom the three criteria did not give identical predictions are summarized in table 2. For all seven, SAUM predicted better than EPM. In five cases, MAUM also outperformed EPM. SAUM predicted better than MAUM for three farmers. MAUM never predicted better than SAUM, and EPM never outperformed SAUM or MAUM.

For the Polonnaruwa, dry zone sample, table 1 shows that there were eight farmers for whom the three criteria exactly predicted the actual land allocations. In one case the three criteria gave the same prediction, but actual land use differed slightly from predicted.

The results for the remaining fourteen farmers in the dry zone sample (for whom the three criteria did not give identical predictions) are summarized in the lower part of table 2. These results show that SAUM predicted better than MAUM in seven cases and better than EPM for thirteen farmers. MAUM outperformed SAUM for three farmers and predicted better than EPM in nine cases. For no farmers did EPM predict better than SAUM or MAUM.

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[1] The adequacy of a sample size of 1,500 was established for a representative case by inspecting the variability of expected utility after each 100 drawings. The mean was found to be quite stable ater about 1,000 drawings, so the conservative sample size of 1,500 was adopted. To sharpen the comparisons, the same sequence of pseudorandom variates was used for each value of x_1 and for both MAUM and SAUM.

The Monte-Carlo procedure is unnecessary for SAUM when the distributions are exactly normal since, if utility is negative exponential, expected utility maximizing solutions are simple functions of mean and variance. However, no analytical solution could be found for MAUM, and the analytical procedure is not applicable when distributions are either skewed or truncated. Consequently, the more general approach was implemented for all cases.

Table 1. Relative Performance of the Three Criteria

Prediction Performance[a]	Kandy Sample	Polonnaruwa Sample
	(number)	
Actual ≡ SAUM = MAUM = EPM	8	8
Actual ≡ SAUM = MAUM > EPM		1
Actual ≡ SAUM > MAUM = EPM		2
Actual ≡ SAUM > MAUM > EPM	1	
Actual ≡ MAUM > SAUM = EPM		1
Actual ≡ MAUM > SAUM > EPM		1
Actual ≢ SAUM = MAUM = EPM	2	1
Actual ≢ SAUM = MAUM > EPM	4	3
Actual ≢ SAUM > MAUM = EPM	2	3
Actual ≢ SAUM > MAUM > EPM		2
Actual ≢ MAUM > SAUM > EPM		1
Total	17	23

[a] ≡ means "is predicted exactly by"; ≢ means "is not predicted exactly by"; = means "predicts equally as accurately as"; and > means "predicts better than."

Accuracy of Prediction

It is evident that SAUM is a better predictor of behavior than MAUM in this study and that EPM is inferior to the other two criteria. What remains to be established is the accuracy of the predictions. The computed optima often differ from actual land use. That one criterion predicts better than another may be of little relevance if the best is a poor predictor of actual behavior. Consequently, accuracy of prediction was measured for each sample and each criterion by calculating the mean absolute deviation (M) of predicted area of MV from actual area as

$$M = \sum_{i=1}^{n} |AA_i - PA_i|/n, \tag{17}$$

where AA_i is the actual area under MV for farmer i, PA is the predicted MV area for that farmer using the given criterion, and n is the sample size. To give a relative measure of predictive accuracy, the value of M was expressed as a proportion of the mean area actually planted.

SAUM was the most accurate criterion with a mean absolute deviation of 10% for the wet zone sample and of 8% for the dry zone sample. For MAUM, the corresponding statistics were 34% and 15%, while EPM showed a low level of predictive power with relative mean deviations of 49% and 29% in the two zones.

Table 2. Frequency of Pairwise Superior Prediction

Kandy Sample: Less Successful Criterion	More Successful Criterion		
	SAUM	MAUM	EPM
	(number)		
SAUM		0(0)	0(0)
MAUM	3(18)[a]		0(0)
EPM	7(41)	5(29)	

Polonnaruwa Sample: Less Successful Criterion	More Successful Criterion		
	SAUM	MAUM	EPM
	(number)		
SAUM		3(13)	0(0)
MAUM	7(30)		0(0)
EPM	13(57)	9(39)	

[a] Figures in parentheses are percentages of the total sample.

Sensitivity Analysis

Sensitivity analyses were performed to study the effects on predictive accuracy of changes in probability distributions and utility functions. Because of the computational burden, the analyses were confined to two case farms (one in each area), considered as representative of the two samples. Parameters varied were the subjective means and variances of yields of the two varieties, coefficients of risk aversion for cash income, subsistence consumption and net income, and scaling constants for the two attributes using MAUM. Herath (pp. 137–44) gives full details of the results. Overall, the predictions based on both SAUM and MAUM generally remained unchanged for moderate changes in the single-attribute functions. For MAUM, similar robustness was found for moderate changes in the scaling constants. However, the predictions were found to be more sensitive to changes in the parameters of the elicited probability distributions.

Conclusion

The comparisons of the predictive power of the three choice criteria show that the two criteria based on expected utility maximization performed generally better and never worse than EPM. In the majority of cases, SAUM outperformed MAUM. The latter result was contrary to prior expectations. It implies either that the farmers studied did not differentiate between subsistence consumption and cash income in choosing varieties to plant, or that the extra complexity of MAUM was a source of inaccuracy in their preferences articulation. The greater simplicity of SAUM along with its predictive accuracy indicates that it is clearly the "best" criterion of the three examined.

An important finding of this study is that SAUM provided a much better basis for predicting behavior than EPM (see also Officer and Halter; O'Mara; Lin, Dean, Moore). That is, land allocations between MV and TV by these farmers can best be explained by considering not only the expected outputs and costs of these technologies but also the individuals' attitudes to risk.

Some limited sensitivity analyses revealed that computed SAUM and MAUM solutions seem to be more affected by changes in probability distributions than by changes in utility functions. If this is true, then accurate elicitation of subjective probabilities is very important if behavior is to be predicted well.

Finally, we found that rice farmers in the two samples appeared to allocate their available land between MV and TV in an economically rational way, by maximizing subjective expected utility of net income.

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Adoption of Interrelated Agricultural Innovations: Complementarity and the Impacts of Risk, Scale, and Credit

Gershon Feder

The paper presents a model of farm decisions which arise when a farm is faced with two interrelated innovations. The innovations are distinguished by their returns to scale, and may be adopted individually. It is shown that under conditions of uncertainty or a binding credit constraint, the intuitive concept of innovations' complementarity may be misleading, and a more relevant definition of complementarity is derived. The latter helps to explain why policies which enhance adoption of one innovation may discourage adoption of the other, even when the two innovations seem to complement each other.

Key words: complementarity, credit constraint, interrelated innovations, risk.

The introduction of yield-increasing innovations has been an important factor underlying the rapid growth of world agricultural output since 1960. Most notable is the "green revolution" technology consisting of high-potential, fertilizer-responsive seeds and related inputs. Indeed, a major share of economists' research efforts in farm level adoption behavior focused on this experience. Most works examined the particular developments in a specific region, providing econometric explanation of observed patterns (Schutjer and van der Veen). While sociologists devoted substantial efforts to modelling farm adoption behavior (Rogers 1962, 1969), relatively few economists addressed this topic with formal models (Hiebert, Kislev and Shchori, O'Mara, Feder 1980, and Scandizzo).

This paper discusses some aspects of adoption decisions using a simple model involving two interrelated, agricultural innovations. The innovations are distinguished by their returns to scale (which lead to differential adoption behavior by farms of different size). The analysis allows consideration of what comprises complementarity in the context of interrelated innovations. Further, the differential impact of policy measures is analyzed and potential dynamic patterns implied by the model are discussed.

The outline of the paper is as follows: section two describes farm behavior under uncertainty; section three discusses model implications. Then, in the fourth section, a binding credit constraint is assumed, and its impact is analyzed. Results are summarized in the last section.

The Model

Assume that a crop yielding R_1 dollars per hectare (with full certainty) has been grown for years by all farmers, irrespective of their holding size, H. Assume, at this stage, that all farmers face similar prices and credit constraints.

Two innovations are now introduced. The first innovation is neutral to scale because its net returns per hectare are not affected by the number of hectares on which it is applied: It will be referred to as innovation N (neutral). The other innovation is lumpy because it has a fixed capacity and requires a fixed installation cost of I dollars regardless of farm size.[1] Its

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[1] When this innovation consists of a piece of equipment, I may represent the annual amortization flow. Alternatively, it may be noted that in many cases lumpy mechanical innovations are being used in rural areas on a rental basis (Staub and Blase, p. 588). Thus, while there is a fixed rental cost, it is far below the investment needed to actually purchase the equipment.

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capacity is assumed to be large enough so that only one level of adoption is relevant. The lumpiness of this technology implies that its cost per hectare (I/H) declines with holding size. It will be referred to as innovation L (lumpy).

The two innovations are interrelated because the average yield per hectare is larger when both are adopted than when only one is adopted. This implies that the two innovations are complementary. This notion of complementarity is rather narrow, however, and the crucial complementarity concept is more complicated. A second interrelation between the two is that the adoption of L affects the level of perceived risk of N.

An example of such innovations is the case of a high yielding grain variety (HYV) and tubewells (Clay). The former is neutral to scale (in the absence of credit constraints), and generally has a higher yield per hectare (if appropriate amounts of fertilizers are applied) than traditional varieties. Tubewells require a fixed investment cost; they further increase the yield gain from HYV, since a regulated water supply is important for realizing the full potential of HYV (Dalrymply, p. 8) and for reducing yield risk.

Adoption of N enables the farmer to obtain, on average, $y(x)$ tons per hectare, where x is a variable input (such as fertilizers) related to the new technology, and y is a production function (per hectare) with the properties $y' > 0$, $y'' < 0$. The unit cost of x is c and the unit price of output is P. Superiority (on average) of N over the traditional crop is assumed: $[P \cdot y(x) - c \cdot x] - R_1 \equiv \pi_1 > 0$ for all x in the relevant range. Assume further that the yield per hectare with N is perceived as uncertain. Thus, output per hectare includes a stochastic element ϵ with mean zero. The thesis that innovations in agriculture usually display higher perceived risk relative to traditional technologies has substantial support in the literature. For instance, Schutjer and van der Veen conclude that "the adoption of (new) agricultural technology may require the adopter to accept a greater degree of risk and uncertainty . . . . The new wheat and rice varieties introduced in the mid-1960s probably increased the uncertainty facing farmers by . . . introducing genetic homogeneity in the variety planted" (p. 23). The role of higher subjective risk is emphasized by Lipton who notes that "risk is in the eye of the beholder . . . for the farmer familiar only with traditional varieties, it is the HYV's subjective risk that counts" (p. 323). Similar views are expressed by O'Mara.

The introduction of innovation L, if not accompanied by N, would increase per hectare income from the traditional crop to R_2 (where $R_2 > R_1$), thus inducing all farmers with holdings larger than $I/(R_2 - R_1)$ to adopt the innovation.

Innovation L is assumed to complement N (and vice versa), so that when both innovations are adopted the average yield per hectare is $q(x) > y(x)$ and $q' > y'$ for all values of x. The perceived yield risk associated with a hectare employing both innovations is $\gamma \cdot \epsilon$, where γ is a positive parameter. Superiority of N over the traditional technology implies that $[P \cdot q(x) - c \cdot x] - R_2 \equiv \pi_2 > 0$ for the relevant range of x. Note, however, that the complementarity of the two innovations—i.e., $q(x) > y(x)$ does not imply $\pi_2 > \pi_1$. In the case of HYV and tubewells, it is likely that $\gamma < 1$ since irrigation reduce risk. But in general, γ could be greater or less than 1.

Farmers are assumed to be risk-averse; hence, they maximize expected utility of income by properly choosing the levels of variables that they control. One decision variable is dichotomous: L can be either adopted or rejected. The decision regarding N, on the other hand, involves an optimal level of adoption since the innovation is divisible. The farmer can thus cultivate a proportion h of his holding using the technology implied by N, where $0 \leq h \leq 1$. The third decision variable is the volume of x to be applied per hectare cultivated with N.

It follows that the optimization problem can be analyzed in three steps: first, the optimal levels of h and x are established subject to "L not adopted" and "L adopted"; the expected utility levels corresponding to the two optimal solutions are then compared to determine whether L should be adopted or rejected.

Accordingly, denote the utility function by U and formulate the following decision problems:

Problem 1: (L not adopted)

$$(1) \qquad \max_{h,x} EU\{H[(\pi_1 + P \cdot \epsilon)h + R_1]\}.$$

Problem 2: (L adopted)

$$(2) \qquad \max_{h,x} EU \{H[(\pi_2 + P \cdot \gamma \cdot \epsilon)h + R_2 - (I/H)]\}.$$

Problem 3 is simply a comparison between the expected utility levels of the optimal solutions to problems 1 and 2.

Results

A straightforward derivation of equations (1) and (2) enables one to verify that the optimal levels of x corresponding to problems 1 and 2 (say x^* and x^{**}) are characterized by the following equations:

$$P \cdot y'(x^*) = c, \tag{3}$$

$$P \cdot q'(x^{**}) = c. \tag{4}$$

Clearly, $x^{**} > x^*$: the optimal level of the variable input per hectare cultivated with N is higher if L is adopted as well. Further, x^* or x^{**} are not affected by the levels of the other control variables nor by uncertainty and risk aversion. However, optimal levels of x are negatively related to the price ratio c/P.

The optimal adoption level of N (defined by h, the proportion of land holding cultivated with N, and denoted by h^*, h^{**} for the respective problems) is characterized by

$$E\big(H(\pi_1 + P \cdot \epsilon)U'\{H[(\pi_1 + P \cdot \epsilon)h^* + R_1]\}\big) + 0, \tag{5}$$

$$E\big(H(\pi_2 + P \cdot \gamma \cdot \epsilon)U'\{H[(\pi_2 + P \cdot \gamma \cdot \epsilon)h^{**} + R_2 - (I/H)]\}\big) = 0 \tag{6}$$

On the basis of results derived from a general model of optimization under uncertainty (Feder 1977), the following can be asserted:

(*a*) Both h^* and h^{**} decline when the variability of ϵ increases.

(*b*) An increase in the fixed cost (I) will reduce h^{**} (but will not affect h^*) if absolute risk aversion declines with income.

(*c*) An increase in γ will reduce h^{**}.

With some further elaboration, the following results can be obtained:

(*d*) The level of h^* decreases (is constant), (increases) with farm size if relative risk aversion increases (is constant), (decreases) with income. Nonincreasing relative risk aversion is a sufficient condition for h^{**} to increase with farm size. If relative risk aversion is increasing, then h^{**} may initially increase and then decrease with farm size.

(*e*) An increase in the cost of x will reduce both h^* and h^{**}.

(*f*) A sufficient condition for $\frac{\partial h^*}{\partial P} > 0$ or $\frac{\partial h^{**}}{\partial P} > 0$ is that relative risk aversion does not exceed the value of 1.

While (*a*)–(*f*) are of a comparative static nature, the variability of ϵ changes over time due to learning-by-doing and better dissemination of information. Thus, the assertion that h^* and h^{**} are negatively related to the variability of ϵ implies that, over time, the adoption rate (for a given farm) of N increases. But at an aggregate level, the pace at which the use of N increases depends on the interrelationship between N and L. The adoption of L is defined by the solution to problem 3 above. This analysis is quite cumbersome without a convenient specification of the utility function and the distribution of ϵ. The model used by Feder and O'Mara proves to be particularly amenable to manipulations and is adopted here. Assume, therefore, that U is a logarithmic utility function, and that ϵ has a two-point distribution, where the values $+\ \sigma$ and $-\ \sigma$ have equal probabilities.

Applying these specifications to equations (5) and (6) yields[2]

$$h^* = R_1 \cdot \pi_1/(P^2 \cdot \sigma^2 - \pi_1{}^2), \tag{7}$$

$$h^{**} = [R_2 - (I/H)]\pi_2/(\gamma^2 \cdot P^2 \cdot \sigma^2 - \pi_2{}^2). \tag{8}$$

Assertions (a)–(c), and (e) above can be easily verified (note that σ^2 and $\gamma^2 \cdot \sigma^2$ are the respective variances of yield when N or both N and L are adopted). Since a logarithmic utility function implies constant (and unitary) relative risk aversion, assertions (*d*) and (*f*) also hold. Evaluating expected utility at the optimal values h^* and h^{**}, problem 3 can be solved. The solution implies that adoption of both N and L is preferred to the adoption of N alone by farmers with holding size higher than a certain critical level H^o, where H^o can be calculated as

$$H^o \equiv I/(R_2 - \theta \cdot R_1), \text{ and} \tag{9}$$

$$\theta \equiv \frac{\{1 - [\pi_2{}^2/(\gamma^2 \cdot P^2 \cdot \sigma^2)]\}^{\frac{1}{2}}}{\{1 - [\pi_1{}^2/(P^2 \cdot \sigma^2)]\}^{\frac{1}{2}}}.$$

The term π_1 describes the average superiority of N over the traditional technology when L is not adopted, and π_2 describes average superiority when L is adopted. The ratios

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[2] The present analysis assumes the conditions $P \cdot \sigma > \pi_1$ and $P \cdot \gamma \cdot \sigma > \pi_2$ to hold since they are necessary for an internal solution of h.

$\pi_2/(\gamma \cdot P \cdot \sigma)$ and $\pi_1/(P \cdot \sigma)$ thus measure the gain per unit of risk obtained, respectively, when both innovations are adopted and when N alone is adopted. The ratio π_2/π_1 measures overall complementarity between L and N, as distinguished from simple complementarity which is defined by the property $q(x) > y(x)$. When π_2/π_1 exceeds unity, the combination of L and N provides a higher per hectare expected gain than that obtained when only N is adopted.

It was shown earlier that if L alone were introduced, then all farms larger than $I/(R_2 - R_1$ would profit from adoption of L. Comparing this result with equation (9) implies that when $\theta > 1$, the joint introduction of N and L inhibits the adoption of L relative to a situation where L is introduced alone, because holdings in the range $\frac{I}{R_2 - R_1} \leq H \leq \frac{I}{R_2 - \theta \cdot R_1}$, which would otherwise prefer adoption of L, will adopt N and reject L. For θ to be larger than 1, $(\pi_2/\pi_1) < \gamma$ must hold, i.e., the measure of complementarity must be less than the risk ratio γ.

The importance of these concepts is evident when the relative magnitudes of h^{**} and h^* are considered. Such a comparison is best performed with h^{**} evaluated at the critical land holding size H^o, since h^* is not affected by holding size while h^{**} is increasing in H. Thus, at H^o

$$\text{(10a)} \quad \text{Sign}\,(h^{**} - h^*) = \text{Sign}\,[(\pi_2/\pi_1) - \gamma^2 \cdot \theta].$$

However, since $[(\pi_2/\pi_1) \gtreqless \gamma] \Rightarrow (\theta \lesseqgtr 1)$, the condition may be reformulated as

$$\text{(10b) for } \gamma > 1 \quad \left[\frac{\pi_2}{\pi_1} > \gamma\right] \Rightarrow (h^{**} > h^*),$$

$$\text{for } \gamma < 1 \quad \left[\frac{\pi_2}{\pi_1} < \gamma\right] \Rightarrow (h^{**} < h^*).$$

The examination of properties of the critical holding size shows that a decrease in the degree of variability (σ) will reduce H^o only if $(\pi_2/\pi_1) > \gamma$. That is, if the superiority per risk unit is higher with adoption of both L and N (versus adoption of N only), then lowering the level of risk induces smaller farmers to adopt L. However, if the index of overall complementarity is lower than the ratio of the corresponding risks (γ), then a reduction in uncertainty will increase the level of adoption of N, but will not induce higher adoption of L (or may reduce it if adoption is reversible). This result may hold even when simple complementarity $[q(x) > y(x)]$ prevails.

A similar result may be observed regarding the impact of subsidies on the cost of variable inputs x (i.e., a reduction in c). As shown above, a subsidization policy will increase the optimal levels of x^*, x^{**}, h^*, h^{**}; but the impact on H^o, which determines whether such a policy will stimulate the adoption of L, may be negative or positive, depending on the condition

$$\text{(11)} \quad \text{Sign}\left[\frac{\partial H^o}{\partial c}\right] = \text{Sign}\left[\frac{\pi_2 \cdot x^{**}}{\pi_1 \cdot x^*} - \gamma^2 \cdot \theta^2\right].$$

Thus, in the case $\gamma < 1$, if π_2 is sufficiently less than π_1, it is possible that a subsidy on x, while encouraging adoption of N, will not stimulate adoption of L. Likewise, in the case $\gamma > 1$, if the ratio (π_2/π_1) is sufficiently less than γ^2, a reduction in c will adversely affect the adoption of L. This result contrasts with the effect of a subsidy reducing I, which induces adoption of L by smaller farmers as well as more intensive adoption of N by all farmers who have adopted L (i.e., $\frac{\partial h^{**}}{\partial I} < 0$ and $\frac{\partial H^o}{\partial I} > 0$).

Subsidies on the price (P) of the crop produced with N were shown earlier to increase (x^*, h^*) and (x^{**}, h^{**}). However, the relation between P and the adoption of L is not necessarily positive as intuition might suggest. It is possible that a higher price will make L less attractive.[3] A sufficient condition for price subsidies to stimulate the adoption of L is $(\pi_2/\pi_1) > \gamma^2$.

The discussion above demonstrates that in the case of interrelated innovations simple notions of complementarity may be misleading. Complementarity should be defined as a situation in which augmenting L by N increases profits (corrected by a risk factor) by more than is obtained when N alone is adopted. Such complementarity does not necessarily exist even under a strong yield complementarity, e.g., a large value for the difference

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[3] The relevant condition is

$$\text{Sign}\left(\frac{\partial H^o}{\partial P}\right) = \text{Sign}\left\{\left[1 - \left(\frac{\pi_2}{\gamma^2 \cdot P \cdot \sigma} \cdot \frac{q}{\sigma}\right)\right] - \theta^2\left(1 - \frac{\pi_1}{P \cdot \sigma} \cdot \frac{y}{\sigma}\right)\right\}.$$

$q[x] - y[x]$, since L may be effective in improving yields even when N is not adopted (thus generating a high value for the difference $R_2 - R_1$).

As mentioned earlier, the parameter of perceived variability σ declines over time because of experience and improved information channels. In the case where $(\pi_2/\pi_1) > \max(\gamma, \gamma^2)$, the dissemination process is at first characterized by a relatively low level of adoption of N by smaller farmers who use little of the variable input x and do not adopt L. The larger farmers, who adopt L, also allocate a larger proportion of their land to be cultivated with N and use a higher level of x. Over time, smaller holdings will adopt L, thus increasing their adoption rate of $N(h^{**} > h^*)$ as well as using more x. In fact, all farmers, whether adopting L or not, will increase their adoption of N over time. Eventually, all farmers may prefer complete specialization with N, if there is no effective lower bound on the risk indicator σ, and all holdings characterized by $H \geq \{I/[P(q - y) - c(x^{**} - x^*)]\}$ will adopt L.

If, however, $\pi_2/\pi_1 < \gamma$, the dynamic pattern sketched above may not be observed. Thus, while use of N will increase over time, the use of L may decline. Since for any given set of innovations the term (π_2/π_1) may differ across agroclimatic zones, different dynamic patterns for the same set of innovations are quite possible.

The Impact of a Credit Constraint

The analysis has thus far assumed that farm operations were not affected by credit constraints. In some cases, however, lack of credit may be an important factor in explaining farmers' reactions to innovations (Lipton, p. 322). This section focuses on a case of binding-credit constraint. For simplicity's sake and in order to isolate the impact of credit, a risk-neutral behavior is assumed.

The cash requirements of farm operations are covered by a variety of sources. The fungibility of credit implies that the tying of credit to particular uses is seldom enforceable (von Pischke, pp. 10–13); thus, aggregating all credit is justified. In terms of the model presented here, a parameter $K(H)$ must be added to denote total cash availability for a farm of size H. The opportunity rate of interest is denoted by r. Assume $K(H)$ increases with H. For simplicity, the following proportional relationship is specified:

$$K(H) = k \cdot H, \tag{12}$$

where k is a parameter denoting per hectare cash supply. Farms smaller than I/k cannot adopt L because of insufficient cash. But as shown later, larger farms may also reject adoption of L.

Since the credit constraint is binding, the cash expenditures of any farm of size H must equal the credit constraint. Thus, for a farm adopting N only, assuming negligible cash requirements for the traditional technology, it must hold that

$$h_1 \cdot c \cdot x_1 \cdot H = k \cdot H, \tag{13}$$

where the subscript 1 denotes adoption of N only. For farms adopting both L and N the corresponding relation is

$$h_2 \cdot c \cdot x_2 \cdot H + I = k \cdot H. \tag{14}$$

Analogous to the analysis of the third section, three decision problems corresponding to problems (1)–(3) may be defined. The only differerences are that presently expected profit (rather than expected utility) is being maximized, and that the maximization is subject to the equality constraints (13) and (14) for problems 1 and 2, respectively. The decisions are characterized as follows:

Problem 1 (L not adopted)

$$\max_{x_1, h_1} H\{h_1[P \cdot y(x_1) - c \cdot x_1 - R_1] + R_1 - r \cdot k\}$$

s.t. equation (13).

Problem 2 (both L and N adopted)

$$\max_{x_2, h_2} H\{h_2[P \cdot q(x_2) - c \cdot x_2 - R_2] + R_2 - (I/H) - r \cdot k\}$$

s.t. equation (14).

As before, problem 3 entails the comparison between the optimal solutions of problems 1 and 2; if profit under 2 is higher, L is adopted together with N.

It is clear that only one control variable is available in each of problems 1 and 2, since the choice of h determines x and vice versa. The first-order conditions for optimum imply

$$P \cdot y(x_1) - R_1 - x_1 \cdot P \cdot y'(x_1) = 0, \tag{15}$$

$$P \cdot q(x_2) - R_2 - x_2 \cdot P \cdot q'(x_2) = 0. \tag{16}$$

One can immediately conclude that the optimal level of x does not depend on the amount of credit available, since (15) and (16) define a unique solution for x_1 and x_2, respectively, and k does not enter in these equations. Equation (16) also shows that the fixed adoption cost of L (I) does not influence the level of x_2; this is somewhat counterintuitive since I competes with x_2 for use of scarce cash. But, as evidenced in (15) and (16), the optimal allocation implies that changes in the credit constraint and cost of L will affect the proportion of land allocated to N (as well as adoption of L) rather than the intensity of input use. A comparison of these results with equations (3) and (4) shows that, without a binding-credit constraint, optimal per hectare input use is negatively related to the ratio c/P, while input use with a credit constraint is positively related to the ratio R_i/P. This holds in the present case because a change in x_i requires an opposite change in h_i (to comply with the cash constraint); the reallocation of a unit of land cultivated with N to the traditional technology, while involving loss of output produced with N, provides R_i dollars of revenue.

Because h_i is inversely related to x_i, it follows that h_i is negatively related to the ratio R_i/P. Thus, a price subsidy will reduce the per hectare use of x, but will increase the share of area grown with N (whether or not L is adopted). The net result is an increase in total output produced with N.

While $x^{**} > x^*$ [and thus $q(x^{**}) > y(x^*)$] under a nonbinding credit constraint, $x_2 > x_1$ is not necessarily true in the present case.[4] Hence, the relation between h_1 and h_2 is not obvious. Since x_1 and x_2 are independent of c and k, expansion of credit and subsidies on c will lead to expansion of area under N (as can be derived directly from [13] and [14]). Similarly, a subsidy on I will increase h_2. As in the third section, h_1 does not change with H, while h_2 increases with H.

To analyze the effects of various policies on the adoption of L, calculate first the critical holding size H_o, distinguishing between adopters and nonadopters of L. Using the definition of problems 1–3, and equations (13) and (14), H_o is

$$(17) \qquad H_o = I(P \cdot q - R_2)/k(P \cdot q - R_2) - k(x_2/x_1)(P \cdot y - R_1) + (R_2 - R_1)c \cdot x_2.$$

Clearly, $\partial H_o/\partial c < 0$, i.e., subsidies on c will increase H_o, and will therefore inhibit the adoption of L. Recall that in the absence of credit constraints the impact of subsidized inputs was ambiguous, depending on overall complementarity.

This results because, with a binding credit constraint, an element of substitutability enters in the simultaneous decisions regarding adoption of the two innovations. A lower cost of inputs certainly makes N more attractive and discourages adoption of L at the margin.

The impact of subsidies increasing the price of output (P) is difficult to ascertain and can be both ways, as it increases the attractiveness of both innovations.

As shown above, an increase in overall availability of credit (i.e., an increase in k) encourages adoption of N. But the effect on adoption of L may be positive or negative, as described by the condition,

$$(18) \qquad \text{Sign}\,\frac{\partial H_o}{\partial k} = \text{Sign}\left[\frac{(P \cdot y - R_1)}{c \cdot x_1} - \frac{(P \cdot q - R_2)}{c \cdot x_2}\right] = \text{Sign}\,[\pi_1/(c \cdot x_1) - \pi_2/(c \cdot x_2)].$$

The explanation of this result is as follows: $(P \cdot q - R_2)$ measures the income gain, for a farm which has adopted L, when a unit of land is reallocated from traditional cultivation to N. Equation (14) shows that $[1/(c \cdot x_2)] = \partial h_2/\partial k$. Thus $(P \cdot q - R_2)/(c \cdot x_2)$ is the total income gain realized on a farm adopting L when credit availability is increased by one unit; the term $(P \cdot y - R_1)/(c \cdot x_1)$ represents the gain from a unit allocated to N on a farm not adopting L. Since these gains are compared for a farm whose profit is originally equal with or without L, a situation $(P \cdot y - R_1)/(c \cdot x_1) > (P \cdot q - R_2)/(c \cdot x_2)$ implies a larger farm where these gains become equal. The essential factor in determining the direction of change stems from the concept of overall complementarity. When the yield cultivated with the traditional technology responds well to the introduction of L, this response may be relatively stronger than that of the yield grown with N, such that, overall, the two innovations should not be viewed as complementary.

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[4] Consider, for instance, the case $y = x^{\frac{1}{2}}$, $q = \beta \cdot y$ and $\beta > 1$. Clearly, model assumptions are satisfied. But application of equations (15) and (16) yields

$$x_1 = 4R_1^2/P^2; \; x_2 = 4R_2^2/(\beta^2 P^2), \text{ and}$$

$$\beta > (R_2/R_1) \Rightarrow (x_1 > x_2).$$

The impact of changes in credit (or cash) availability on the adoption is of particular interest since it could imply certain dynamic patterns: As farmers' income increases over time due to the adoption (even partial) of innovations, more savings per hectare may be expected, increasing the amount of cash available for farm operations.

Summary and Concluding Remarks

This paper provides some results concerning adoption patterns for interrelated innovation. A simplified case is presented where two innovations are introduced simultaneously: One innovation is neutral to scale, while the other's cost decreases with farm size. Some of the results are expected while others seem initially counterintuitive (see table 1). They depend to some extent on the specific assumptions underlying the models, but focus attention on policy implications. The introduction of agricultural innovations usually is done by some official agency. Such agencies use a number of tools to promote the innovations and their speedy adoption. These policies, which include subsidies on input and output prices, special credit facilities, and various methods to disseminate information may have differential effects on adoption of apparently complementary components of a new technological package.

This paper demonstrates that a careful examination of the interrelationship between the different components is essential to determine whether or not complementarity exists. Such examination cannot ignore endogenous constraints, such as risk aversion, affecting farmers' decisions since they are an integral part of complementarity. Policy measures also need to account for exogenous constraints such as credit scarcity, because response may differ depending upon whether or not such constraints are binding.

Thus, yield complementarity (even after direct cultivation and adoption costs are deducted) is not necessarily an indicator of genuine complementarity. If it is not, policies (such as price or cost subsidies) which encourage adoption of one component may discourage the other.

Table 1. Summary of Comparative Static Results

Effect on / Increase in	Case A: Credit Constraint Not Binding					Case B: Credit Constraint Binding				
	x^*	h^*	x^{**}	h^{**}	H^0	x_1	h_1	x_2	h_2	H_0
P	+	$+^{a}$	+	$+^{a}$	$\left.\begin{matrix}+\\0\\-\end{matrix}\right\}$ if $[1 - \pi_2 \cdot q/(\gamma^2 \cdot P \cdot \sigma)] \gtreqless \theta^2[1 - \pi_1 \cdot y/(P \cdot \sigma)]$	−	+	−	+	?
c	−	−	−	−	$\left.\begin{matrix}+\\0\\-\end{matrix}\right\}$ if $\frac{\pi_2}{\pi_1} \cdot \frac{x^{**}}{x^*} \gtreqless \gamma^2 \cdot \theta^2$	0	−	0	−	−
I	0	0	0	−	+	0	0	0	−	+
σ	0	−	0	−	$\left.\begin{matrix}+\\0\\-\end{matrix}\right\}$ if $\frac{\pi_2}{\pi_1} \gtreqless \gamma$					
γ	0	0	0	−	+					
k						0	+	0	+	$\left.\begin{matrix}+\\0\\-\end{matrix}\right\}$ if $\frac{\pi_1}{x_1} \gtreqless \frac{\pi_2}{x_2}$
H	0	$+^{b}$ 0 −	0	$+^{c}$ 0 −		0	0	0	+	

[a] The sign is obtained under the sufficient condition that relative risk aversion (RRA) does not exceed 1.

[b] The sign is positive, zero or negative if RRA is decreasing, constant, or increasing in income.

[c] The sign is positive if RRA is constant or decreasing. It could be negative if RRA is increasing.

Subsidies to reduce variable input cost will increase per hectare application when credit is not scarce, but may have no effect when credit is constrained. Output price subsidies, on the other hand, may reduce the per hectare intensity of variable input use with effective credit constraint. The opposite result occurs with abundant credit. It is then possible for variable-input cost subsidies to encourage adoption of both the divisible and lumpy components of a new technological package. However, scarcity of credit implies that subsidies will stimulate adoption of the scale-neutral innovations while discouraging the lumpy ones.

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Estimation of Recreation Benefits from Measured Utility Functions

P. A. Findlater and J. A. Sinden

Indifference maps from two-attribute utility functions can provide demand curves to value the benefits of the attributes or goods. The Ramsey model is one method to estimate the functions, and an alternative related method is presented in this paper. A comparative estimation of a given recreation benefit indicates that the alternative may be a significant improvement over Ramsey. The alternative is simpler and faster. It is applied, apparently successfully, to estimate a five-good utility function. This function is then used as the objective function in a linear program to value changes in recreation benefit when substitute activities are introduced.

Key words: recreation benefits, unpriced benefits, utility functions, valuation.

In 1974, Sinden presented a method to estimate utility functions, their indifference maps and demand curves to value recreation activities. The benefit values were validated, but each survey interview took three hours. In three other applications of the method (Sinden 1978), interview time was reduced to two hours. Nevertheless, further reduction is necessary for large-scale surveys. Another drawback is the method's unrealistic restriction to two goods in the utility function.

The object of this paper is to present and test a new method to provide the same information in a considerably simpler and faster manner. This simplicity and speed is demonstrated by estimating a multiattribute function over five goods—not just two as with the original method.

The argument proceeds as follows. The existing procedure, the Ramsey method, is reviewed first. Next, the new development (probabilistic rating) is described, and both are applied to evaluate recreation visits to a national park in Australia. The methods' difficulties are then outlined; the results are presented, and the methods are compared. Finally a multiattribute utility function is estimated with the probabilistic rating method. Demand curves for park recreation are derived with and without a substitute activity. This is an empirical test of Knetsch's argument that the existence of substitutes places upper bounds on people's willingness to pay for new facilities.

The Two Methods

The policy problem concerns the allocation of resources to park or beach development in southern Queensland, Australia (Findlater). More specifically, Lamington National Park and the Gold Coast beaches are day-visit destinations for one million nearby permanent residents and perhaps an extra million summer visitors. Both are heavily visited and are recreation alternatives. Estimates of the value of recreation at the park would assist in the allocation of public resources between these locations.

The methods rest on a questionnaire approach. All the chosen interview subjects lived in the major city of Brisbane (81% of those visiting the park came from Brisbane) and twenty subjects were interviewed. All subjects were presented with both methods. Each method can be used to estimate indifference maps from which demand curves and benefit values can be derived. But they differ in the way they derive the maps, as we now consider.

The Ramsey Method

The Ramsey method rests on a game where the subject chooses between two prospects

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(table 1). Each prospect contains two outcomes, each with a specific probability of occurrence. One of the four outcomes is varied until the subject is indifferent between the prospects. The data at indifference are used to derive a point on a total utility curve. The game is repeated for additional points on the curve (Sinden 1974).

The first step in the actual analysis is to define as recreation activities the four outcomes, labelled (i) to (iv) in table 1. In all Ramsey applications the key activity for the particular policy problem is entered as outcomes (i) and (iii). Findlater was attempting to value the benefits of park visits, so these two outcomes are defined as quantities of this activity (P). In the first game for each subject the quantity of outcome (i) is conveniently defined as 0 days P. The quantity of outcome (iii) is specified as n days P, and n is determined in the interview.

Outcome (ii) is defined as the best alternative recreation activity to P, at the time of the interview. For these subjects it was invariably visits to the beach (B). In the first game the quantity of B was set at one day. The activity in outcome (iv) was defined as a neutral activity, that is one which is neither substitute nor complement to the key activity in outcomes (i) and (iii) (Sinden 1974). This neutral activity (NA) was defined as staying at home.[1]

An arbitrary quantity is inserted for n and the subject is asked, "Do you prefer prospect I or prospect II, or are you indifferent between them?" If he is indifferent the game stops. If he prefers prospect II, n is lowered, to move toward indifference. If he prefers prospect *I*, n is raised. The question is repeated and n is adjusted until the subject is indifferent between prospects.

When the subject is indifferent between the prospects, the total expected utilities (U) of the two prospects are equal. For example, let $n = 1$ in table 1. With an indifference level of 1 for n we know:

$$(1)\quad 0.5U\ (0 \text{ days } P) + 0.5U\ (1 \text{ days } B) = 0.5U\ (1 \text{ days } P) + 0.5U\ (NA).$$

Multiplying by 2.0 and transposing,

$$(2)\quad U(1 \text{ days } B) - U(NA) = U(1 \text{ days } P) - U(0 \text{ days } P).$$

Equation (2) deserves further explanation. Two quantities of the good to be valued occur on the right-hand side. The left-hand side acts as a constant utility interval so that the difference between $[U(1 \text{ days } B)]$ and $[U(NA)]$ is scaled and constant. Equation (2) might, therefore, be rewritten:

$$(2')\quad [U(1 \text{ days } B) - U(NA)] = U(1 \text{ days } P) - U(0 \text{ days } P).$$

The given amount of utility denoted by the combined left-hand side equals the difference in utility between the two items on the right-hand side.

A second game (table 2) was played where the indifference value of n in position (iii) in game 1 became the quantity of P in position (i) in game 2. The value of n in game 2 was found as before to give another equation at indifference. Let the value of n be 3, for example. From table 2, and following equations 1 and 2, we have

$$(3)\quad [U(1 \text{ days } B) - U(NA)] = U(3 \text{ days } P) - U(1 \text{ days } P).$$

The scaling of utilities began by setting an arbitrary base level and arbitrary utility scale. Let $U(0 \text{ days } P) = 1$ and let the constant utility interval of $[U(1 \text{ days } B) - U(NA)] = 5$ utiles.[2] Equations (2) and (3) now gave the following three points on a total utility curve,[3] U(0 days

Table 1. The Ramsey Model of Utility Estimation, Game 1

Probability	Prospect I	Prospect II
0.5	(i) 0 days P	(iii) n days P^a
0.5	(ii) 1 days B	(iv) NA

[a] Let the value of n be 1 at indifference.

Table 2. The Ramsey Model of Utility Estimation, Game 2

Probability	Prospect I	Prospect II
0.5	(i) 1 days P	(iii) n days P^a
0.5	(ii) 1 days B	(iv) NA

[a] Let the value of n be 3 at indifference.

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[1] Findlater's subjects "handled" the game satisfactorily without the need to specify the quantity of days of this neutral activity. The game can proceed as long as one day of the activity in position (ii) is preferred to the neutral activity.

[2] The base is arbitrarily set here at 1 and not 0 as in the earlier paper (Sinden 1974). Here we need to multiply the base utility in the developed method so the base utility cannot be 0.

[3] The values are calculated as follows. Insert the base and interval figures in equation (2) to give

$$5 = U(1 \text{ days } P) - 1,$$

so $U(1 \text{ days } P) = 6$ utiles. This calculated value (6) and the interval figure (5) are inserted in equation (3) to give, $U(3 \text{ days } P) = 11$.

$P) = 1$, $U(1 \text{ days } P) = 6$ and $U(3 \text{ days } P) = 11$.

More games were played to estimate more points on this first total utility curve. The games followed game 2 in table 2. The indifference quantity of n in game $m - 1$ always became the quantity of activity P in game m. The new quantity n is found to give a new point on the curve. This process was repeated until the quantity of P reached a predetermined time horizon or until the subject is unable to answer the question (do you prefer prospect I or prospect II or are you indifferent?) at the large quantities of P.

The indifference value of n is carried over between games to enable the subject to "move along" a total utility curve. This permits an arithmetic estimation of utilities. Consider equations (2′) and (3). The indifference quantity of n from table 1 (1 days P) is carried over and is present in both equations. This, together with one known value [$U(1 \text{ days } P) = 0$] and the known arbitrary scale value of the left-hand side, leaves only one unknown in each equation. The pair of equations can, therefore, be solved for the utility of the new, higher quantity of the good to be valued. Thus we move continuously along a total utility curve.

So far a single total utility curve has been estimated. This process illustrates the Ramsey method and provides perspective for the alternative method. The final two steps with Ramsey are to estimate a set of total utility curves and transpose the set into an indifference map. Benefit values can then be calculated from demand curves derived from the map. These two steps were detailed in Sinden (1974) and expanded in Sinden (1980) so they are not pursued here.

The Probabilistic Rating Method

The Ramsey method requires three steps to reach an indifference map. This new development obtains the map in a single step, saving interview time. We call it "probabilistic rating."

Subjects were presented with pairs of prospects, as in table 3. All four positions (i) to (iv) were filled with given quantities of two activities. Prospect 1 was a convenient base with an arbitrary utility rating of 1.0. Outcome (ii), in prospect 2, was the same as outcome (iv) and outcome (iii) was a different amount of the good in position (i). In this example, P is the activity of interest and was placed in positions (i) and (iii). Activity B, in positions (iii) and (iv), is the best alternative activity.

Table 3. The Probabilistic Rating Method, Game 1

Probability	Prospect I	Prospect II
0.5	(i) 0 days P	(iii) 1 days P
0.5	(ii) 1 days B	(iv) 1 days B
Utility Rating	1.0[a]	t[b]

[a] This rating of 1.0 is a convenient, arbitrary base point.
[b] The rating t is found by direct questioning. Let it be 2.0.

The subject was asked, "How do you rate the utility (t) of prospect II relative to prospect 1?" To illustrate, let rating t be 2.0 for the prospect II in table 3.

From table 3 we know:

$$(4) \quad 2\{0.5[U(0P)] + 0.5[U(1B)]\} = 0.5\,[U(1P)] + 0.5\,[U(1B)].$$

Multiplying by 2.0,

$$(5)\; 2[U(0P) + U(1B)] = U(1P) + U(1B).$$

The combination ($0P$, $1B$) is represented by point I in figure 1 and the associated utility [$U(0P)$, $U(1B)$] is rated at the arbitrary 1.0. The combination of activities on the right-hand side of equation (5) is represented by point II, and rated at 2.0. The relative utility of

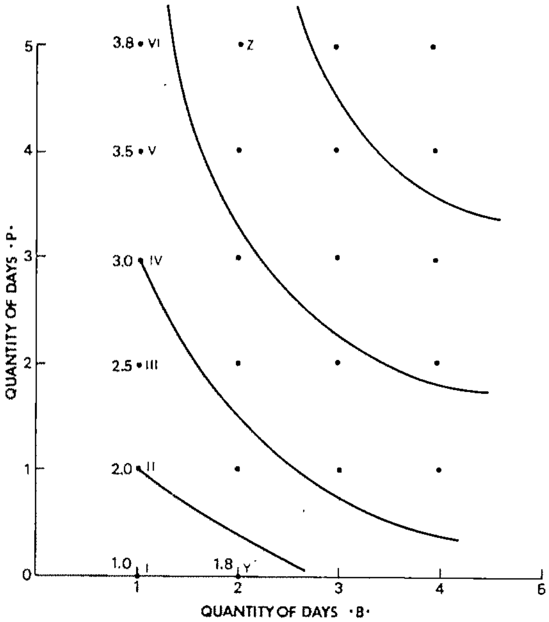

Figure 1. Points on an indifference map derived with the probabilistic rating method (with illustrative curves sketched in)

two points on the map are now rated. Further points are rated as follows.

(*a*) The outcomes in positions (i), (ii), and (iv) were held constant in table 3. New quantities of activity *P* (specifically 2*P*, 3*P*, 4*P*, and 5*P*) were inserted into position (iii) to define the new prospects (respectively prospects III, IV, V, and VI). The game was repeated to rate the new points "above II" in figure 1 and these ratings are also shown on the figure.

(*b*) Outcome (iv) was changed to 2*B* and outcome (*iii*) to 0*P* to represent point *Y* (in figure 1) relative to point *I*. Point *Y* was rated in the usual way and, to illustrate, let the rating be 1.8.

(*c*) The process of step (*a*) was repeated for a set of points between *Y* and *Z*.

(*d*) Finally, outcome (iv) was changed to 3*B* and then to 4*B* and steps (*a*) to (*c*) repeated to derive utility ratings, relative to point *I*, for a whole set of points on the map.

The positions of each of this set of points are shown in figure 1. For simplicity, numerical ratings are illustrated only for the points derived in steps (*a*) and (*b*). Some hypothetical, but plausible, indifference curves have been sketched onto the figure to illustrate the indifference map.

In applying the method, the indifference map was expressed mathematically as a utility function.

Estimation of Benefit Values

Both methods were applied to each of the twenty subjects. To avoid bias, the order of the methods was randomized. The benefit values for park visits for each subject were obtained as areas under the subject's demand curve calculated from his indifference map and budget lines. This standard procedure is explained by Sinden (1974).

An important prior step to estimating benefit values was to standardize the utility numbers. The numbers in both methods had a common base, $U(1B, 0P) = 1$ utile, but the intervals differed.[4] For example, the Ramsey method gave the utility of the interval $[U(1B, 0P)$ to $(1B, 5P)]$ as 16 utiles, whereas probabilistic rating gave an interval value of 4 utiles. To compare the two methods requires that both the utility intervals and the base be common. The Ramsey number of 16 was adopted for this interval and the results from the other method adjusted to it. The adjustment required multiplying all utility interval values by the ratio of (utiles in Ramsey) to (utiles in probabilistic rating).

Relative Difficulties between the Methods

The difficulties with the methods are now discussed in order of importance. The theoretical difficulties come first.

(*a*) The price/budget information for both methods was often difficult to obtain because subjects sometimes found it hard to estimate budgets and define prices. Unfortunately the benefits were often very sensitive to the budgets. We spent little time in refining questions to obtain price and budget data in order to concentrate on collecting utility data. However, we see no major difficulties in improving the quality of the budget data through closer questioning.

(*b*) Indifference curves should be convex to the origin and continuous. But some subjects seemed to receive no extra utility from extra quantities of one of the goods offered. The portions of their indifference curves that we collected were not convex to the origin—making it difficult or sometimes impossible to derive demand curves. Other subjects had "terraced" indifference curves because their planning period was in terms of whole days rather than fractions of a day. For these subjects the utility function from probabilistic rating may not show true preferences.

(*c*) The Ramsey model rests on an arbitrary utility interval of, in this case, $[U(1 \text{ day } B) - U(NA)]$, equation (2′). This interval sometimes proved too great to detect the satiation that occurs when marginal utility reached zero. Both methods suffer from this difficulty.

The second kind of problem occurs when subjects encounter difficulties in playing the games. In these cases, games were not completed or preferences changed within and between games. The games were new so the first method was always harder for the subject to understand. The following specific difficulties were encountered.

(*d*) All models rest on judgments between prospects involving probabilities and the subject may not understand the nature of probabilities despite the analyst's explanations.

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[4] A utility of 1.0 for combination (1*B*, 0*P*) was calculated for Ramsey when the utility curves were derived. This base utility number is arbitrary, so it could also be standardized when necessary.

(*e*) Interviews were often interrupted because the total interview time for the two methods was about one and a half hours. An effect of this was that subjects sometimes appeared to change preferences.

(*f*) Each subject had to make decisions for the whole family but the subject's preferences may differ from those of the family. The subject's response occasionally may be confused between his own preferences and those he attributed to the family.

(*g*) Subjects may "second-guess" the interviewer with answers that they think he expects.

In general, Ramsey seemed to present the most difficulties and probabilistic rating the least. The Ramsey method requires some prior knowledge of the subject's preferences whereas the probabilistic rating method does not. It was usually more difficult for a subject to nominate the number of days for indifference between prospects for the Ramsey method, than to rate the two prospects for the probabilistic rating.

Results

Benefit values were obtained from thirteen subjects for Ramsey and from fourteen for probabilistic rating. The results are compared for the thirteen subjects with values from both methods. The difficulties just discussed are the reasons why some subjects had no values. The total benefit from days two, three, and four at the park varied from $8 to $1,085. The following two criteria are used to choose between the two methods.[5] (*a*) The Ramsey method is an established procedure. Does the alternative give similar benefit values? If so, choose the method with least resource costs. (*b*) Choose the method which provides most results for a given resource cost. "Most results" could be more data from a given individual or the same results from more people.

Similar Results for Lower Resource Costs?

Six out of thirteen values from probabilistic rating deviated by less than 10% from their corresponding Ramsey values. Four out of thirteen deviated by 11% to 25% from corresponding Ramsey values. Thus ten out of thirteen deviated by 25% or less from Ramsey. Three out of thirteen deviated by more than 25%. A 25% range seemed a subjectively reasonable level of accuracy because it would still permit a choice between the land-use alternatives. The development seems therefore to give similar results to Ramsey.

The distribution of times for the thirteen probabilistic rating interviews, relative to Ramsey, was as follows. Six of the thirteen interviews took 50% to 90% less time than Ramsey, two took 25% to 49% less time, two were within 9% of Ramsey and three took over 10% more. Thus ten of the thirteen subjects had similar times (within 9%) or less with probabilistic rating.

The new method gave similar results to Ramsey and generally had shorter interview times. In fact, the average time per interview was twenty-eight minutes for Ramsey and twenty for probabilistic rating. The probabilistic rating method is some 30% faster than Ramsey and appears to be the best method with this criterion.

More Results for the Same Resource Costs?

The probabilistic rating method gave similar results to Ramsey at some 70% of the average time needed for Ramsey. Indeed, the method elicited sufficient data for a utility function in only some twenty minutes. Logically then, more results should be obtained in the same interview time. A potential improvement would be a utility function with more than two goods, because most choices involve more than two alternatives. Accordingly, the probabilistic rating method was extended to multiple alternatives.

Estimation of a Five-Attribute Utility Function and Demand Curves

Consider the following three recreation activities in addition to day trips to the nearby national park (*P*) and the nearest beach (*B*): fishing (*F*), picnic recreation at Copeton reservoir (*C*), and picnic recreation at a gorge site (*G*).

The two prospects must now have five possible outcomes, each of which has an equal (0.2) probability of occurrence. The basic game for the probabilistic rating method is illustrated in table 4. To begin, a simple base prospect was selected as prospect I and arbitrarily assigned a utility rating of 1.0. Compared to prospect I, prospect II has a simple one-unit change in one good. The utility rating for prospect II, designated as "t" in the table, is found by direct questioning.

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[5] The value of the first extra day was sometimes indeterminate because some statistical models gave demand curves asymptotic to the price axis. Comparative benefit values were therefore estimated for the second, third, and fourth extra days at the park.

The nature of the gambles and choices is explained in the usual way. Then the rating question is posed: "How do you rate the utility from prospect II relative to prospect I?" A single subject, selected to illustrate the method said, "60% more." So the utility rating of prospect II is 1.6. A new set of outcomes is inserted for a new prospect II, the game repeated for a new value of t.

A series of such games was played with the subject comparing each prospect II to the constant base prospect I. The quantities of the various recreation activities were steadily and systematically raised and all combinations up to four days of each good were rated. The relationship between the prospects in table 4 may be interpreted as follows.

If

$$(6)\quad 1.0 = 0.2[U(1P)] + 0.2[U(1B)] + 0.2[U(1F)] + 0.2[U(1G)] + 0.2[U(1C)],$$

then

$$(7)\quad 1.6 = 0.2[U(2P)] + 0.2[U(1B)] + 0.2[U(1F)] + 0.2[U(1G)] + 0.2[U(1C)].$$

Multiply the right-hand sides of equations (6) and (7) by 5 to give the following: if

$$(8)\quad 1.0 = U(1P) + U(1B) + U(1F) + U(1G) + U(1C),$$

then

$$(9)\quad 1.6 = U(2P) + U(1B) + U(1F) + U(1G) + U(1C).$$

The first game (table 4) gave equations (8) and (9), and each successive game gave further equations of the same type. The ratings of the left-hand sides of equations (8) and (9) are dependent on the independently varied quantities on the right-hand side. The utility ratings were, therefore, regressed on the quantities of goods from the whole set of equations from all the games.

All possible cross-product terms were tested to investigate for nonseparable and nonadditive utilities. The two models with the highest t-statistics, and also the highest adjusted coefficients of determination, were as follows:

$$(10)\quad U = -1.88 + \underset{(10.1)}{0.50P} + \underset{(17.9)}{0.89F} + \underset{(15.1)}{0.75G} + \underset{(7.2)}{0.40C} + \underset{(5.2)}{0.27B},$$

where $\bar{R}^2 = 0.89$;

$$(11)\quad U = -0.37 + \underset{(4.1)}{0.21P} + \underset{(11.3)}{0.59F} + \underset{(9.0)}{0.46G} + \underset{(2.3)}{0.12C} + \underset{(6.9)}{0.5\,(P.F.G.C.B.)},$$

where $\bar{R}^2 = 0.92$. The t-statistics are in parentheses; both equations were based on fifty-three sets of observations, and both had forty-eight degrees of freedom. The necessary data for these five-attribute functions were obtained in a forty-five-minute survey.

There seems little statistical reason to prefer one equation over the other. Equation (11), with the multiplicative term, is a nonlinear utility function. Equation (10) is a linear utility function, implying substitution between activities at constant rates. This evidence on substitutability follows the subject's intuitive description of the relative desirability of the activities. Further, the linear, additive equation (10) is suitable for the objective function of a linear program if the constant can be dropped. A geometric program would be required for the curvilinear equation (11). Thus equation (10) is selected to derive the demand curve.

Table 4. A Probabilistic Rating Game to Derive a Five-Attribute Utility Function

Prospect	Probability of Each Outcome	Prospective Outcomes	Utility Ratings
I	0.2	$1P$, $1B$, $1F$, $1G$, $1C$	1.0
II	0.2	$2P$, $1B$, $1F$, $1G$, $1C$	t[a]

[a] The rating t is found by direct questioning.

Estimating Demand Curves

Equation (10) was used as the objective function in a linear program. The optimal quantity of each activity at given prices must be observed so the value of the total utility is not required. The constant in the equation can therefore be omitted without analytical loss. The seven constraints were a budget limit, a total time constraint of twelve days, and a maximum of four days per activity. The price of *P* was varied and associated quantities observed to obtain a demand curve.

The price of *P* was varied between $10 and $30 to give demand curve 1 (shown by the *X*'s in figure 2). At a price of $10, the subject takes four days, but at $12.60 he takes zero days because the beach activity (*B*) offers more utility per dollar and replaces *P* in the optimal solution. Activity *B* therefore substitutes for *P*. The substitute was effectively removed by pricing it at $30 instead of its actual $10. The process was repeated to give demand curve 2. At a price of *P* of $30 per day the subject takes 1.3 days *P*. However at $31 he takes zero *P* because his budget is exhausted. In recreation terms all of these prices represent the marginal cost of the activity.

Effect of the Substitute Activity

Knetsch has argued that substitutes place upper bounds on willingness to pay for new facilities. Howe endorses this view and the concept that the demand curve for the new facility will be truncated. The upper bound of $12.6 and such truncation are well illustrated in figure 2. Howe concludes that direct-survey and travel-cost methods may capture total and not net benefits of new facilities. He proposes a change to the travel-cost theory that "potentially allows" for substitution.

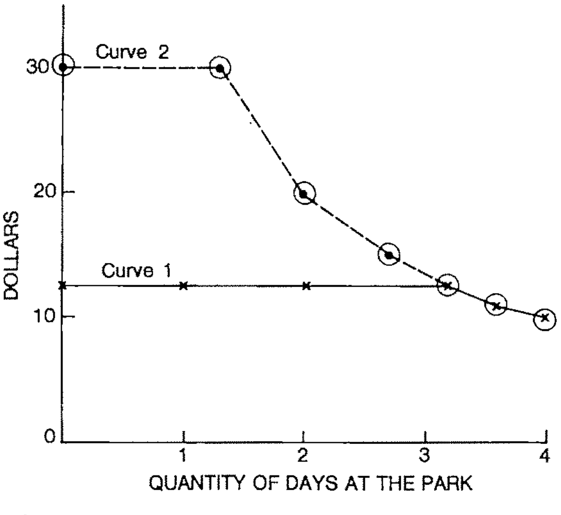

Figure 2. Demand curves for days at the park (*P*) with (curve 1) and without (curve 2) the substitute

The present procedure appears to be a practical way to estimate demand curves with and without the substitutes. Figure 2 shows that without the substitute, the subject is willing to pay $20 for unit 2, $13 for unit 3, and $10 for unit 4. Ignoring the first unit, the total benefit is $43. With the substitute, the subject is willing to pay $12.5 for units 2 and 3 and $10 for unit 4, for a total of $35. Thus, an analysis which ignored substitutes would overestimate benefits for this one subject by $8, or 23%.

Conclusions

The new probabilistic rating method of eliciting utility functions has been presented, applied, and compared to the standard Ramsey method. The comparison suggests that the new method has some desirable and improved performance characteristics.[6] Probabilistic rating gave similar results (benefit values) as Ramsey but with considerably shorter interview times. It, therefore, seems the more useful of the two methods.

Probabilistic rating was extended to obtain data for a five-good utility function in a forty-five-minute interview with a single subject. This utility function was then used to derive demand curves for a recreation activity, with and without substitutes. This derivation seems to be a practical empirical procedure to estimate the effect of substitutes.

What is the potential value of the probabilistic rating method? Its success rests largely on the reliability of responses to the rating question. Our subjects found this question easier to understand than the question for *n* in the Ramsey method. Probabilistic rating is faster and simpler than the Ramsey method. Application to the larger scale problem, with five recreation activities, proved simple—once we had worked out the principles reported here. The subsequent derivation of benefit values through regression analysis and linear programming was straightforward. The whole strategy seems sufficiently direct and comprehensive to be widely applied to investigate propositions and derive values.

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[6] We have not made any experimental comparisons of probabilistic rating against the direct question or other valuation techniques. So we have not attempted to report on such comparisons, despite our intuitions from this research and our other studies such as Sinden and Worrell.

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Notes

The Scarcity Syndrome

Don Paarlberg

There is a new mindset about farm and food matters that may affect us profoundly in years ahead. After half a century of conventional wisdom that the farm problem was one of surplus, today's perception is that the problem is shortage. I call this the "scarcity syndrome." It has seeped into farmer attitudes, economic analyses, and legislation. It has helped escalate farmland prices and the demand for credit. It will probably profoundly affect commodity programs during the 1980s. We are not sufficiently aware of the far-reaching effects of this new attitude. In this note I examine the scarcity syndrome—its validity and effects.

Some Evidence

First, I shall marshall some evidence, accurate and otherwise, that appears to support this new attitude.

Prices

Farm product prices have been rising irregularly. In 1980, they were two and one-half times the 1967 level. People naturally associate higher prices with smaller quantities; the superficial explanation of a higher price is a shorter supply.

Not only have farm product prices increased, virtually all prices have risen. The farm cost of fuel is four times as high as in 1967 and we know that short supply was partly to blame. We hear that we are running out of other natural resources such as timber, iron ore, and manganese. We read that we are going to have less of almost everything. The scarcity syndrome has affected other sectors as well as agriculture.

Income

Average net incomes of farm people, which for many years had been low relative to nonfarm people have been rising steadily. Almost all income from farming is earned in the market place. Government payments were 21% of net income from farming as recently as 1972; in 1979 they were 5%. The market seems to be treating farmers better than formerly. The natural inclination is to attribute this to tighter supplies.

Weather

The conventional wisdom is that, except for 1980, recent weather has been better than we can continue to expect and that crop yields in years ahead are likely to reflect poorer average growing conditions than recently. This appraisal contributes to the scarcity syndrome.

Exports

World population is increasing and per capita incomes are rising. The United States is now evidently committed to supplying the growing overseas market. From 1971/72 to 1979/80 the physical quantity of U.S. farm exports increased two and one-half times. In 1980, exports took one-fourth of U.S. agricultural production. Between now and the year 2000, the world population is expected to grow 35%. Per capita incomes abroad are also expected to increase. Our foreign customers will try to upgrade their diets, demanding more feed grains and soybean meal. The prevailing view is that the United States will be supplying much of this additional demand and experiencing stress on its capacity to produce.

Gasohol

If existing blueprints are followed, several hundred million bushels of corn will be converted to alcohol annually by 1985. This will be in addition to an increase in the use of corn for sweetening. The combination of corn for export, corn for alcohol, corn for sugar, and corn for feed adds credibility to the scarcity syndrome.

Farmland

The conventional wisdom about farmland is that "they're not making any more of it." We dispute how many acres are lost annually to urbanization and how many to erosion. But the arguments deal only with magnitudes; the directions are conceded.

Crop Acreage

In 1981, virtually no acres were withheld from production under government programs. As recently as 1972, farmers set aside 62 million acres, 16% of our cropland. The obvious conclusion is that we now have no real cushion of unused acreage for meeting future needs.

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Grain Stocks

World carryover stocks of grain, which were recently rebuilt from low levels of 1974–75, were drawn down. At the end of the 1980–81 marketing year, they were about the same, relative to consumption, as during the mid-seventies world food scare. For the United States, the feed grain carryover was only a little above pipeline stocks.

Water

With rising energy prices and falling water tables, pump irrigation is becoming uneconomical across the Great Plains, Southwest, and Far West. Some acres now irrigated will return to lower-yielding dryland farming.

Efficiency

It is alleged that the backlog of agricultural technology has been mostly pulled off the shelves. The argument is that great numbers of farmers used to lag far behind the leaders in per acre yields. The game of productivity "catch-up" provided huge gains in total output. But now, it is said, improved practices are in fairly general use. Few breakthroughs are anticipated for the leaders. Efficiency and productivity are known to have declined in nonfarm sectors; it is alleged that they are leveling off in agriculture too.

Research

Federal contributions to the experiment stations have been virtually stagnant in real terms for fifteen years. The customary conclusion is that adequate new knowledge is not being developed and that this will reduce future agricultural productivity.

Farm Population

In 1921, the farm population totalled 32 million. Today it is about 6 million. One way of looking at this is to say that the human resource in agriculture has been depleted. Therefore, few people will offer their labor in agriculture. Consequently, production is likely to be less than if this adjustment had not occurred.

Energy

Farm production undoubtedly will be made more difficult by rising energy costs, reflected in higher prices for fuel, fertilizer, pesticides, and other inputs. These rising costs are likely to squeeze out some marginal production, exacerbating scarcity.

Regulation

Environmental regulations are expected to curtail some technically efficient farm practices. Some farm chemicals not only are increasing in cost, their use is being challenged. If they are used, crop production will be more costly than before. If their use is denied, yields will decline. Either path seems to put a brake on production.

The Analysis

Analytical work supporting the scarcity syndrome comes from multiple sources: The Worldwatch Institute (Brown), the Department of Agriculture (Penn), the International Food Policy Research Institute (Mellor), the Food and Agricultural Organization of the United Nations, and the World Food Council (Tanco). Four recent reports of the Carter Administration reflect the scarcity syndrome: *The Global 2000 Report to the President* (Speth and Pickering), *Overcoming World Hunger: The Challenge Ahead* (Presidential Commission on World Hunger), *The National Agricultural Lands Study,* and the *Summary Report on the Structure of Agriculture* (USDA 1981). A pessimistic background for the present mood came from two reports to the Club of Rome: *Limits to Growth* (Meadows), and *Mankind at the Turning Point* (Mesarovic). People in these agencies read and reinforce each other's work, using similar methods of analysis. Thus they do not provide entirely independent assessment.

Taken together, these perceptions make a strong case. This mood has been picked up by most farm and food industry groups. Less has been said about it by the farm lobby because this view is not consistent with the surplus scenario of the past fifty years, nor is it consistent with big commodity support programs. Farm lobbyists fear that if farmers give up their old rationale they may lose the commodity programs.

We have had brief periods of concern in the past about the adequacy of food supplies. There was a short neo-Malthusian food scare after World War II, 1946–47, when expanded postwar needs coincided with a poor U.S. crop. There was another in 1964–65 with a poor crop in South Asia. There was another, much worse, in 1966–67, when drought struck India's Bihar province. Then came the recent world food scare during 1973–75, associated with poor crops in a number of countries. At the time, these various episodes were considered by some analysts to be unfortunate departures from normal. However, the prospective scarcity situation, as popularly perceived, has a more long-run tone. The bountiful 1981 crop blunts this view but does not abolish it.

The Earlier Surplus Scenario

The scarcity syndrome is more striking because it follows an opposite assessment which gripped us for 40 years—that our problem was surplus. The surplus scenario also was based on a set of perceptions, of course, different. Their focus was that we had excess agricultural capacity and that resources in agriculture could not be voluntarily withdrawn (Cochrane and Ryan, p. 15; Johnson and Quance). The visible confirmation of the surplus scenario was the pileup of commodities in government hands and the idling of cropland.

The surplus scenario had some illusion to it. For instance, total agricultural production during the five first and worst years of the Great Depression, 1930–34, was actually 2% below the production of the five preceding years (USDA 1942). This is contrary to the general perception. Surplus stocks did accumulate, true enough. But that happened because we priced our products above market-clearing levels. From 1928–30 to 1959–61, under the surplus illusion, we held cotton production constant at 14.4 million bales. Meanwhile, cotton production in the rest of the world more than doubled. The cotton market was there, but we shut ourselves off from it and piled up a government "surplus." A major law of economics is that if a competitive product is priced above equilibrium, a surplus will accumulate no matter what the physical volume of production is.

Interestingly, during the years 1978–80 when the scarcity syndrome arose, total U.S. agricultural production averaged 7% above average production of the three previous years in spite of a poor crop in 1980 (USDA 1980). Again, the mood eclipsed the statistics.

We seem to have escaped the surplus scenario, but we should beware of replacing it with an opposite mindset. When perception inclines one toward a particular view, impressive evidence can be marshalled in its support. Opposite evidence can be overlooked without intent to deceive. The scarcity syndrome, currently dominant, needs careful examination rather than fashionable endorsement.

When market prices of farm products recently moved above supports, we exported enormous quantities and drew set-aside acres into use. Essentially, the supply and demand for agricultural products came into equilibrium with approximately full use of U.S. agricultural resources. This should not surprise a good analyst. It is what will happen in a market-oriented industry. That we have moved from a government-induced surplus into a market-oriented equilibrium should not persuade us that the next stage necessarily will be shortage. But some people mistrust the market and think that government must manage things. To such people, if there is no longer a surplus to be managed there must be a scarcity to be supervised. The idea of a market-induced equilibrium is alien to those who inherently mistrust the market.

The force that pushes up prices of farm products and everything else is, in my view, an excess of money and credit, not a shortage of commodities. The force that pushed down prices of farm products and everything else during the Great Depression was a shortage of money and credit, not commodity surplus. Few good prescriptions ever flow from wrong diagnoses. What we need is management of the volume of money and credit, not management of the supply and price of agricultural products.

Assessments

I now examine briefly and critically some indicators often cited to support the scarcity syndrome.

Efficiency

The allegation that agricultural efficiency is tapering off is not established. Productivity—total output per unit of total input—has worked its way irregularly upward during the past century. The record shows that agricultural efficiency continues to advance, although efficiency declines in the nonfarm sector. Allegations that efficiency gains in agriculture are tapering off cannot be supported by examining the record, as can be seen in table 1.

Present farm practices provide new yield increments which are declining. This is true. It is always true of any operational technique. But there likely will be new techniques; there always have been, ever since agriculture changed from an art to a science. What will they be? Who knows? Maybe gene-splicing. Maybe textured soy protein. Maybe nitrogen fixation for nonleguminous plants. Maybe weather modification. Maybe salt-tolerant crops. Maybe hydroponics. Maybe wide crosses, like triticale. Maybe twinning of beef calves. Maybe improved photosynthesis. Maybe supplemental irrigation. Maybe computer-aided management. We cannot tell. Agricultural research is like drilling for oil; you never know whether you are five feet from a million dollars or a million feet from five dollars. Yet every now and then somebody strikes oil. It is contrary to experience to expect all dry holes. However, a mindset conditioned by the scarcity syndrome can produce this pessimistic outlook.

Research

It is true that real federal outlays for research by the agricultural experiment stations have been stagnant for fifteen years. But other agricultural research has increased. Expanded work has come from the

Table 1. Annual Average Rates of Changes in Productivity in U.S. Agriculture, 1870–1979

Period	Percentage Change
1870–1900	1.0
1900–1925	−0.2
1925–1950	1.3
1950–1965	2.2
1965–1979	1.8

Source: Durost and Barton, Durost and Black.

states and from such nontraditional sources as liberal arts colleges, federal agencies other than the Department of Agriculture, private research establishments, the international research network, and agribusiness firms. Farmers themselves generate new knowledge. In the aggregate, the nonfederal inputs vastly exceed the USDA contribution. In addition, other countries have expanded agricultural research. Annual expenditures for global agricultural research have increased over fivefold since 1951, and threefold since the early 1960s. (Wittwer)

We cannot obtain an accurate estimate of the output of new agricultural knowledge by measuring the input of one small contributor. It is narrow to conclude that unless the United States does it, nothing happens. But the scarcity syndrome leads us to that conclusion.

Weather

No one knows what the weather will be like in the years ahead. Long-range weather forecasting has not yet reached a stage at which it is useful. Unfortunately, when it comes to predicting next summer's weather, the *Farmers Almanac* is still about as good as anything else. Changes in climate can be identified in retrospect. But with present knowledge they cannot be anticipated with sufficient accuracy to be of much help in decision making.

Farmland

The U.S. Soil Conservation Service says there are 127 million acres of land, not now tilled, that could be converted to cropland, if prices were attractive, in one or two decades (National Agricultural Lands Study). This is in addition to the present cropland base of 413 million acres, a potential 30% increase. True, these additional acres would not be as productive as those now tilled. They would be more erosive. However, we are far from using our land with real intensity, as anyone who knows about agriculture in Japan or Western Europe will testify.

We convert about 675,000 acres of cropland to urban and other nonagricultural uses each year, one-fifth of one percent of our cropland (National Agricultural Lands Study, p. 83). The figure in popular use is three million acres per year, a number which includes forest, mountain, desert, and rangeland. Inclination to use the larger (and erroneous) rather than the smaller (and more nearly accurate) figure reflects the power of the present mindset. Urbanization of cropland can be very disruptive locally, but it poses virtually no threat to our national agricultural potential.

Erosion is more serious. Up to now we have been able to more than offset erosion damage by improving production technology. That may continue to be so for at least a time. To set matters in perspective, the Soil Conservation Service considers erosion loss of five tons per acre or less to be "tolerable," in that losses up to this level are considered capable of being sustained without reducing long-term soil productivity. Seventy-six percent of U.S. cropland experiences losses of five tons a year or less (USDA SCS).

The surplus scenario and the scarcity syndrome seem totally different. But in one respect they are strikingly similar. Both largely ignore the effect of price on the quantity supplied and demanded. In both cases the supply curve is assumed to be perpendicular to the base or nearly so, and the demand curve likewise. The supply situation is assumed to result from changes in technology, the resource endowment, structural characteristics, or other attributes distinct from price. The assessment is that price is unable to do a satisfactory job of allocating resources; therefore, in both cases, a strong role is prescribed for government.

Self-Fulfilling Analyses

The surplus mindset convinced us that prices were low because of a surplus. Protecting farmers from low prices became the central objective. So we sought to increase prices. With prices supported above market-clearing levels, production was stimulated and demand reduced. The result was that products piled up in government hands. The prospect of surplus, therefore, became self-fulfilling.

What might be the result of our new mindset, focused on shortage? One view is that shortage gives the food industry a chance to gouge consumers with high prices. Thus, buyers should be protected from such exploitation. A citizenry which is 97% nonfarmers might be so inclined and might cast about for ways to hold down food prices. Signs of such attitudes are visible all around us.

What are the tools for holding down the food prices, if that objective should be sought? Here are three, all of them used to some extent during the world food scare of 1973–75.

Embargoes, which keep food at home and clog the domestic market with heavy supplies.

Direct price controls.

Manipulation of government-owned or government-managed food reserves to depress prices.

All of these interventions were, in my opinion, unfortunate. The embargoes raised questions about our credibility as a reliable supplier. Direct price controls created the illusion that inflation was no longer a problem. This provided the background for expansive monetary policy and the subsequent price explosion when price controls were removed. The disposal of government stocks, prompted by an eagerness to hold down retail food prices, was premature. It left us with cupboards bare when a real need arose.

If a cheap food policy were strongly used and long continued, the result would be to stimulate demand and inhibit production, so that the scarcity mindset would become self-fulfilling. Those who predicted the shortage could then congratulate themselves on their foresight, just as those who, half a century earlier, diagnosed that problem as one of surplus.

The consequences of a deliberate cheap food policy would be disastrous:

Low prices and low incomes for farmers. These are disincentives for future production and would worsen rather than alleviate scarcity.

Reduced export earnings and injury to our trade balance. This could produce a fall in the dollar's exchange value.

Loss of access to our exports on the part of poor countries who need our food supplies.

Impairment of our international good will. We would be charged correctly with abdicating our role in the global food network.

With inflation and a scarcity syndrome, a cheap food policy can have great political appeal. If a cheap food policy is seriously pursued, farmers should fight it with every weapon at their command.

Conclusion

We cannot know with accuracy the scale of agricultural production in the years ahead. But, if we persist in public policies that price our products far above equilibrium we shall create a surplus, even though we might not have had one in the beginning. If we price them substantially and continually below the market we shall induce scarcity, even though the original scarcity may have been an illusion. These concepts become self-fulfilling.

The best way to avoid these dangers is to allow the market to price our products, with help from some techniques which improve the functioning of the market. Such a system, coupled with responsible management of money and credit, will encourage the volume of agricultural output suited to our resources and our needs, avoiding both surplus and shortage.

If there is indeed difficulty in meeting the demand for food and if prices are allowed to respond, farmers will get the signal. They will increase output, bringing supplies into adjustment with markets at new and higher prices. It is this capability for price adjustment and response that is often omitted from econometric models. A common error is to use short-term coefficients of supply and demand in the analysis of long-run policies. There is an old saying: high prices are the best remedy for high prices.

The scarcity syndrome is an untested hypothesis, not an established fact. An unquestioning embrace of this new and fashionable mindset might not only be wrong; it could lead to some very bad public policies.

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Households and Farm Establishments in the 1980s: Implications for Data

Lyle P. Schertz

This paper relates to three issues. First is Bonnen's conclusion that the inadequacy of our "information processing" is primarily a design and conceptual problem stemming from the ways that " . . . data are collected, analyzed and acted upon by decision makers" (Bonnen 1975, pp. 754, 761). Second is Upchurch's 1974 reiteration of an earlier challenge by Trelogan for economists to be "involved in the process of developing a better system of data for the food and fiber industry." Third is the author's frustrations in using available data and information to appraise changes in resource organization and management in U.S. farming. This paper describes a way to think about the farming subsector of agriculture in terms of households as well as establishments. It suggests, in turn, a conceptual framework for the collection of related data and information.

Agricultural Economists' Tradition of Interest in Data Systems

The profession's concern about data systems and related adjustments has focused heavily on farm income estimates (Bonnen 1972, Carlin and Smith, Hildreth, Nicol, and Weeks and Schluter). Data series to measure the use of nonfarm resources in farming and the nonfarm income of farm operators have been constructed. Recent efforts to improve data series culminated in a revised set of farm sector financial and income accounts (USDA 1980). In line with Nicol's recommendations, recent changes align farm-related estimates with national income and product account measures. Estimates of operator income encompass returns for labor, capital (including land), and management provided by farm operators. Other estimates measure returns to equity in farm assets.

Our data systems focus almost exclusively on farm operators. However, they are an increasingly heterogenous group. Some operators provide practically all resources used on their farms. Others concentrate their efforts on entrepreneurial activities, renting or hiring the services of practically all resources used on their farms. Yet, in many of our data series, no distinction is made among operators regarding these differences.

The concepts in this paper are generally consistent with changes being made by USDA. However, they differ in that, conceptually, the approach presented here encompasses all households that provide resources. Thus, this approach includes operator households but does not exclude other households if they provide resources to farming. In practice not all households would be included in a related data system. For example, households involved as shareholders of large farm input suppliers may not be included.

Further, the concepts in this paper suggest ways to classify operator households and farm establishments. For example, they are consistent with the reality that in many situations, more than one household participates in the operation of any one farming establishment. Any one of these households may also be providing resources to two or more farming establishments—"the places on, or in, which the production process occurs" (USDA 1980).

Income and Wealth Distribution among People

Farm structure issues relate to many aspects of farming (USDA 1979, Schertz et al.). Some of these issues include the way that resources are organized and managed in farming and the distribution of incomes, including the capital gains, associated with owning these farm resources. Other issues relate to opportunities to acquire farm assets and realize related income and the distribution of government benefits and costs of government programs, policies, and rules. Each of these features involves the distribution of income and/or wealth among households—a unit for investigation which is meaningful to the economics of the welfare of people.

The need for household information is further underscored by important changes in agriculture about which we know rather little. They include the following:

(*a*) The great heterogeneity in the organization and management of farm resources. Combinations

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The author is appreciative of reviews and suggestions by Harold F. Breimyer, Don Paarlberg and an anonymous referee. Further, the paper draws freely on a continual exchange with colleagues in the Economic Research Service, other agencies of the U.S. Department of Agriculture, and the Agriculture Division of the Bureau of the Census.

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of resource ownership and use have been changing, and they vary widely.

(*b*) The separation of ownership and use of resources which is likely to increase, especially with land. Statistics indicate that hired labor as a proportion of total labor used in farming has increased. Informal reports indicate that machinery rentals have increased.

(*c*) The tendency for many households that own resources used in farming to become very wealthy as streams of income and associated farm land asset values have increased in the past eight years (Schertz et al.).

Current Data Geared to "One Farm, One Farmer, One Farm Household" Concept

Our current data systems generally imply that individual farms are associated with an individual household that includes a resident farmer. The emphasis is on farm operators. These data systems provide limited information about hired laborers and nonoperator landlords. Information about the nonfarm income and nonfarm wealth of the households providing resources such as land, capital, labor, management, and entrepreneurship in farming is even more limited.

Bonnen suggests that there are two developments which cause conceptual obsolescence. (*a*) "changes in the organization and nature of the food and fiber industry," and (*b*) changes in the "agenda of food and fiber policy" (Bonnen 1975). The schema presented in this paper relates to both types of obsolescence. It could facilitate measuring change in industry organization and is adaptable to farm structural and commodity issues.

Observers of our data recognize the nonfarm dimensions of farm-related households (Carlin and Handy, Lee). However, in the end, the profession always emphasizes farm income and assets rather than data that could reveal economic and financial characteristics of nonoperator households as well as those of farm operator households and establishments. These voids are at least partially explained by the lack of an adequate conceptual framework.

In the absence of adequate data and research, farm related data is often used as if (*a*) individual households are associated with individual farms; (*b*) these households do not have significant nonfarm incomes or assets; and (*c*) nonfarm households do not own farm assets, do not operate farms and, therefore, do not have farm-related incomes. Note, for example, how discussions about agricultural policies often emphasize concepts such as farm population and farm-nonfarm income comparisons.

U.S. farming, in fact, deviates dramatically from the "one farm, one farmer, one farm household" model (Upchurch 1979). Returns to the households are joint returns for the resource combinations employed. Today, only a small proportion of U.S. farm production comes from farms with a single owner-operator family providing all or a major part of the management and capital (machinery, energy, etc). Instead, the major portion of U.S. farm products comes from establishments that obtain resources from several different households with characteristics quite unlike operator households. In spite of these changes, much of our data are collected and represented as if the "one farm, one farmer, one farm household" model continues to prevail.

A Resource Ownership and Use Separation Model

The way that farm resources are organized and managed is shifting from one extreme model—one farm, one farmer, one farm household—toward another model—resource ownership and use separation. This second model involves the separation of ownership of nonland as well as land resources. Separation of capital ownership from its use (machinery and dairy cow rental, for example) and separation of labor ownerhip from its use (hired labor, for example) are involved. Importantly, "use" in this context refers to the individuals who receive the entrepreneurial return from the employment of the resources. In the extreme version of this model, no single household provides more than one kind of resource. However, these individual households may have nonfarm income and assets.

In resource acquisition, however, most of today's farm establishments fall somewhere between the extremes of these two models. For example, one household (which has one or more members who are the operators) may provide all entrepreneurial resources, but only some of the other resources. Other households provide the remaining resources. The household providing the entrepreneurial input for the farm may not provide any resources to nonfarm establishments. The other households providing resources to the farm establishment may or may not provide resources to other nonfarm establishments. Obviously a large number of differing combinations are possible.

Establishment Data Cannot Substitute for Household Data

Changes in farming have stimulated proposals to organize data on the basis of establishments. For example, Upchurch proposes orienting data systems to farm production establishments with flexibility in defining establishments for different types of farming. He sees a correspondence of data collection for farming to data collection for other businesses such as retailing and manufacturing. This orientation would be very useful for understanding the total food system. For example, it could support estimates of " 'income from agricultural production' in contrast to current estimates of 'farm income' " (Upchurch 1979, p.1).

However, establishment data will not adquately support analysis of structural implications of alternative policies and programs. Establishment data could provide information about the ownership of resources used in establishments. But, they would not likely do so, and they are even less likely to provide information about the household characteristics of the resource owners, such as their nonfarm income and assets. Yet, this kind of information is important if we are to understand changing combinations of resource ownership in farming establishments, the extent to which resource ownership and use is separated, and the distribution of income and wealth among people involved in farming.

A Possible Approach

The juxtaposition of the two extreme models suggest approaches for data collection and investigation.

(*a*) What is the distribution of farming establishments along a continuum between the two models? Does the distribution vary among resources, products, or regions?

(*b*) What is the nature of competition among the different kinds of farming establishments?

(*c*) What is the distribution of income and wealth among the different households which provide resources to farming establishments?

(*d*) To what extent do households that provide resources to farming also provide resources to nonfarm establishments?

A combined system of data including information on establishments and households would be useful. Accounts for resource supplies and income flows (and their distributions) among establishments and related households could be provided. Also, distributions of nonfarm economic activities, income, and wealth could be generated. Such accounts could yield data on assets, earned income by source, and government payments to all households involved in USDA programs from suppliers of farming resources as well as food stamp recipients Such data would be helpful in evaluating income and wealth distribution effects of alternative policy and program provisions. It would be important also to examine and perhaps improve the price and transaction series for resource categories, such as farm land prices.

This approach, or some variation of it, should guide the future collection and presentation of data. Priorities among the different sets of data called for by this conceptual framework will depend on the priorities which society and policy makers place on various issues. These, in turn, will generate specific "demands" for information and analysis. For supply response analysis, establishment data are usually adequate. Wealth effects of income flows to households are probably not crucial to reliable supply response estimates.

In contrast, if analyses are required for decisions concerning economic need, such as the level of incomes as criteria and justification for program activities, an understanding of the households involved is important.

There is a tendency for analyses to focus on firms and establishments. In turn, policy makers, economists, and other agriculturalists often use analyses based on establishment data to support policy appeals on equity and distribution grounds. For example, an aura of equity surrounds terms such as "fair price," "parity," and "cost of production." Focusing on operators tends to blend establishment and household information together. However, many people—including economists, at times—often overlook the economics of other households that provide resources to farming. And they also may neglect the nonfarm dimensions of operator households when facing policy questions involving equity.

Regardless of the eventual decisions about agricultural data, the conceptual framework presented here may facilitate an understanding of gaps in our data as well as the limited ability of existing data to represent reality.

Intellectually, a situation where establishment data is used in the 1970s and now in the 1980s as if they represented "one farm, one farmer, one farm household" farms is not satisfactory. Policy makers, of course, bear a heavy responsibility for how they use information. But, in a larger sense, economists and statisticians bear the greater responsibility if they do not devise data and related research and analysis systems that are consistent with issues being addressed by society and policy makers alike.

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Farm Size, Tenure, and Economic Efficiency in A Sample of Illinois Grain Farms

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The analyses in this paper are an attempt to determine if differences in economic efficiency can be discerned for two important structural dimensions of a sample of Illinois cash grain producers. These dimensions are size of operation and the degree to which the land input is owned by the farm operator. Such information can be helpful in the debate concerning the most appropriate economic structure for U.S. agriculture (General Accounting Office; Schertz et al.).

The Model and Study Area

The sample consists of 311 Illinois cash grain farms. Data were obtained from the Illinois Farm Business Farm Management Association (FBFM) records for the year 1977. Selected characteristics for these farms are presented in table 1. These farms were relatively homogenous in enterprise mix and had a useable data record in the FBFM system for more than one year. Obviously this is not a random sample. However, selection of record-keeping farms has the advantage that the management factor should be more homogenous across the structural dimensions being evaluated.

A major goal of the analysis was to determine the relative economic efficiency of moderate-sized commercial farms compared to larger-sized operations. This can indicate the extent to which continuing expansion of midwestern cash grain farms is necessary to achieve economic benefits which can be transferred to consumers (Swanson and Sonka). It is also relevant because of the debate about the future viability of the "moderate-sized family farm" (Tweeten and Huffman). Hence, the sample of farms for this study was subdivided into (*a*) a smaller-farm category (less than 700 acres in size) and (*b*) a larger-farm group (more than 700 acres). Seven hundred acres was selected as a dividing point because Illinois cash grain farms larger than this size typically require in excess of eighteen months labor with current technology (Wilken and Kesler). The smaller farms, therefore, can be operated using predominantly operator and family labor. Less than 25% of the labor used on the smaller sample farms is hired labor, table 1.

Although economic efficiency is difficult to measure, the unit profit function of Lau and Yotopoulos does provide an approach. The degree to which the firms differ in technical and pricing efficiency and the extent to which they are profit maximizers can be estimated with this technique.

As shown by Lau and Yotopoulos, the value of this approach can be enhanced if input demand functions for the variable inputs are jointly estimated with the profit function. Therefore, the following three equations are estimated using the seemingly unrelated regression method which accounts for the correlation in the error terms between the profit function equation, equation (1), and the input demand functions, equations (2) and (3):

$$(1)\quad \mathrm{Ln}\pi = \mathrm{Ln}\beta_0 + \beta_1 D_s + \beta_2 \mathrm{Ln} W + \beta_3 \mathrm{Ln} CE + \beta_4 \mathrm{Ln} LS + \beta_5 \mathrm{Ln} FC + \beta_6 \mathrm{Ln} AC + \beta_7 \mathrm{Ln} PRODY + \beta_8 \mathrm{Ln} BA/CA + \sum_{k=1}^{5} \alpha_k RD_k + e_1,$$

$$(2)\quad -WL/\Pi = \beta_9 D_s + \beta_{10} D_L + e_2, \text{ and}$$

$$(3)\quad -CE/\Pi = \beta_{11} D_s + \beta_{12} D_L + e_3,$$

where Π is variable profit per farm (output price times quantity produced minus labor costs and expenditures for other variable inputs); D_s, smaller farm dummy variable (equal to 1 if farm size is less than 700 acres, 0 otherwise); W, monthly wage rate for hired labor per farm; WL, total wage bill for hired labor per farm; CE, cash expenditures for variable inputs per farm; LS, months of operator and family labor available per farm; FC, value of nonland capital available per farm; AC, acres per farm; $PRODY$, soil productivity index; BA/CA, ratio of soybean to corn acreage; RD_k, regional dummy variable; D_L, larger farm dummy variable (equal to 1 if farm size is greater than 700 acres, 0 otherwise); α_k and β_m are estimated coefficients; and e_j is the error term for the jth equation.

The standard profit function, consistent with a Cobb-Douglas production function, assumes that variable profits are a function of variable input prices and the level of fixed factors. In this analysis, hired labor and cash expenditure items (fertilizer, seed, fuel, pesticides, etc.) are regarded as variable inputs. Fixed factors of production are reflected in

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Table 1. Selected Characteristics of the Sample of Illinois Grain Producers: 1977

	Small-Farm Group	Large-Farm Group
Number of farms	259	52
Average tillable acres per farm	459.9	940.3
Average percentage of tillable acres in		
Corn	59.9	63.9
Soybeans	39.2	34.8
Percentage of total labor usage which is hired	20.9	41.8
Cash expenditures per tillable acre	$99.87	$101.13
Value of nonland capital stock per acre	$128.72	$117.49

Source: Wilken and Kesler.

the three stock variables (*LS*, *FC*, and *AC*). In past unit profit function studies, own-labor has been treated as a variable input. For the U.S. family farm, however, the operator's labor input should be regarded as a fixed input in the same fashion as machinery and buildings. Although operator labor has an opportunity cost, it can best be reflected as a stock variable in a short-run, profit-maximizing context. Thus, the labor inputs are divided into hired labor (a variable input) and operator labor (a fixed input). A pleasing offshoot of this formulation is that operator labor does not have to be valued since it becomes a stock variable expressed in physical units.

Because agricultural production is subject to considerable price and yield variability, additional variables ($PRODY$, RD_K, BA/CA) are included in (1) to reflect their impact on unit profit for the cross-sectional data used. Because the profit function is specified in a short-run context, the effect of soil productivity (*PRODY*) on profitability must be considered. With higher soil productivity, one would expect short-run profitability to be higher for any given level of input use. The index, which has been standardized for different soil types, is a per farm measure of productivity for Illinois crops (Fehrenbacher et al.).

The regional location dummy variables (RD_k) are necessary because of differing weather throughout Illinois. The six regional dummies used in this analysis are consistent with the reporting districts of the Illinois Cooperative Crop Reporting Service. Farm profitability is influenced by output mix as well as efficiency in input usage. In the long run, the ability to select (on the average) the appropriate output mix is an important component of economic viability. However, for any given year, unexpected changes in the overall demand and supply situation may alter relative prices and result in levels of profitability not related to economic efficiency. As a result, the ratio of the acreage of soybeans to the acreage of corn on each farm is included to account for unexpected changes in the relative prices and profitability between the two crops. Consistent with past use of the unit profit function approach, the dollar figures for variable profit, wages for hired labor, and cash expenditures are normalized by the price of output. Because the data in this study are reported on a calendar year rather than marketing year basis, the output price data from the actual farm records for 1977 could not be used to calculate variable profits for the 1977 crop. Instead the average price received by all Illinois farmers for each crop in 1977 was used in estimating profits (Illinois Cooperative Crop Reporting Service). Annual regional price differences were not important in Illinois. As the data base only provided information about expenditures for variable inputs, both price and quantity effects are captured in the regressions. Using total expenditures instead of input prices makes the expected sign of the regression coefficient unclear. Increases in the expenditure variable may result from increased prices or increased quantity usage or both. Higher input prices, *ceteris paribus*, result in lower profits. However, higher input usage will increase quantity produced and may generate higher profits.

Estimation Results and Hypothesis Testing

Prior to pooling the data, separate equations for the two size categories were estimated and the error terms tested for heteroskedasticity between equations (Maddala). The null hypothsis of homoskedastic error terms could not be rejected. In addition, the profit function assumes the underlying production function for each group is identical up to a neutral efficiency shift parameter. Specifically, it assumes that the estimated coefficients are stable across equations. This hypothesis was tested by estimating separate equations and applying a test for the equality of the coefficients (Huang, O'Connor and Hammonds). Results of this test support the use of the profit function for examining relative economic efficiency.[1]

Estimation results of (1), (2), and (3) are presented in table 2 as Model I. In general, the signs of the estimated coefficients are consistent with the theoretical foundation of the profit function. The negative coefficient for hired labor is as expected but is relatively insignificant. The positive coefficient for the cash expenditures variable indicates that the input quantity effect appears to outweigh the price effect. The most significant variables are those associated with individual farm characteristics and regional impacts, i.e., acreage,

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[1] The computed F-value for this test was 1.02 compared to a critical value of $F(13,279) = 1.76$ at the 5% level. The hypothesis that the estimated coefficients are equal across equations is not rejected.

Table 2. Estimation of Cobb-Douglas Profit, Labor Demand, and Cash Expenditure Demand Functions for Illinois Grain Producers, 1977

	Model I[a]	Model II[b]
Variable profit function[c]		
Ln β_0	−.093	.137
	(.056)	(.569)
Ds	.025	.019
	(.042)	(.042)
Ln *W*	−.006	−.011
	(.033)	(.034)
Ln *CE*	.100	.109
	(.052)	(.053)
Ln *LS*	.004	.0004
	(.036)	(.037)
Ln *FC*	−.009	.005
	(.027)	(.028)
Ln *AC*	.958	.925
	(.064)	(.066)
Ln *PRODY*	.799	.772
	(.095)	(.097)
Ln *BA/CA*	−0.133	−0.134
	(.026)	(.026)
T	—	−.180
		(.083)
RD_1	−.081	−.069
	(.050)	(.052)
RD_2	−.165	−.153
	(.041)	(.041)
RD_3	−.013	−.011
	(.032)	(.083)
RD_4	−.095	−.093
	(.032)	(.032)
RD_5	−.177	−.175
	(.055)	(.055)
Labor demand function		
D_s	−.030	−.030
	(.003)	(.003)
D_L	−.049	−.049
	(.006)	(.006)
Variable input demand function		
Ds	−.584	−.586
	(.017)	(.017)
D_L	−.585	−.585
	(.038)	(.038)

[a] Model I is comprised of equations (1), (2), and (3).
[b] Model II is comprised of equations (5), (2), and (3).
[c] Numbers in parentheses are standard errors.

soil productivity, regional climatic conditions, and the ratio of soybean to corn acreage. As soil productivity increases, short-run profitability also increases significantly. The negative coefficient for the soybeans-to-corn ratio indicates that corn was the relatively more profitable crop for the period considered.

Two of the stock variables, operator labor and nonland capital, were not statistically significant. This may reflect an excess supply of these inputs for many of the farms considered. The coefficient for land is positive and strongly significant.

In order to test for efficiency between the two farm size groupings, a set of hypotheses are examined with *F*-tests on restrictions placed across equations. These tests are presented in table 3. First, the hypothesis of equal relative economic efficiency is examined by testing if $\beta_1 = 0$. (β_1 is the coefficient for the smaller farms dummy variable, D_s, in equation [1]). This hypothesis is not rejected indicating that the smaller farms are as efficient as the larger ones.

Tests 2 through 5 in table 3 concern pricing efficiency for hired labor. Tests 6, 8, and 9 are for absolute pricing efficiency in variable inputs other than hired labor. Failure to reject these hypotheses implies that for either or both groups the marginal value product of an input is equal to its input price. In all three cases the hypothesis of equal absolute pricing efficiency is rejected. Because only expenditures data are available for the nonlabor variable input category, one would probably not expect either size grouping to display absolute pricing efficiency. The hypothesis that both groups display equal relative pricing efficiency (test 7) cannot be rejected.

For hired labor, the hypothesis of equal absolute pricing efficiency for both farm size groups (test 2) is rejected as is the hypothesis of equal relative pricing efficiency (test 3). However, tests 4 and 5, which separately consider the possibility of equal absolute pricing efficiency for the two size groups, cannot be rejected. Thus, the results of these four tests seem to be contradictory. However, the standard error on the hired labor coefficient in the profit function, β_2, is relatively large. Therefore, the tests utilizing this coefficient are likely to have relatively little discriminatory power and should be correspondingly discounted.

In addition to the above hypotheses, it is possible to examine for the existence of economies of scale. This should provide further insight into the relationship between farm size and economic efficiency. If the sum of the coefficients of the fixed factors (i.e., $\beta_4 + \beta_5 + \beta_6$) is equal to one, then constant economies of scale exist (Lau and Yotopoulos). The null hypothesis was tested using a *t*-test. The *t*-ratio of −.713 indicates that at the .05 level the null hypothesis of constant scale economies could not be rejected for this sample of grain producers.

In summary, the tests imply that the smaller farms appear to be equally as economically efficient as the larger ones. The two farm groups appear to be equally efficient with respect to relative pricing and efficient for variable inputs other than hired labor, but they do not display equal relative pricing efficiency for hired labor. The finding of constant economies of scale is consistent with equal economic efficiency for both groups.

Table 3. Tests of Hypotheses for Sample of Illinois Grain Farms, 1977

Test Number	Hypothesis Tested	Hypothesis Maintained	Computed F Ratios[a] (Degrees of freedom) Model I[b]	Computed F Ratios[a] (Degrees of freedom) Model II[c]
1	$\beta_1 = 0$	$\beta_1 = 0$	.381 (1,915)	.226 (1,908)
2	$B_2 = \beta_9 = \beta_{10}$		5.076 (1,915)	4.846 (1,908)
3	$\beta_9 = \beta_{10}$		9.399 (1,915)	9.399 (1,908)
4	$\beta_2 = \beta_9$	$\beta_2 = \beta_9$	.584 (1,915)	.362 (1,908)
5	$\beta_2 = \beta_{10}$	$\beta_2 = \beta_{10}$	1.856 (1,915)	1.432 (1,908)
6	$\beta_3 = \beta_{11} = \beta_{12}$		87.001 (1,915)	88.049 (1,908)
7	$\beta_{11} = \beta_{12}$	$\beta_{11} = \beta_{12}$	.0002 (1,915)	.001 (1,908)
8	$\beta_3 = \beta_{11}$		171.222 (1,915)	173.44 (1,908)
9	$\beta_3 = \beta_{12}$		124.837 (1,915)	126.385 (1,908)
10	$c = 0$		— —	5.269 (1,908)

[a] Critical values for the F-test are: 3.84 at the 5% level with $(1,\infty)$ degrees of freedom and 6.64 at the 1% level with $(1,\infty)$ degrees of freedom.

[b] Model I is comprised of equations (1), (2), and (3).

[c] Model II is comprised of equations (5), (2), and (3).

The 700-acre dividing point was selected because of the prior information that Illinois grain farms larger than this size would be larger than the typical single operator family farm (Wilken and Kesler). Hence, this criterion is useful for comparing economic efficiency on moderate-sized versus larger farming operations. Model (I) was also estimated using 500 and then 400 acres as the dividing point. For the 400-acre criterion, the sign and significance levels of most variables were similar to those in table 2. However, the finding of equal economic efficiency ($\beta_1 = 0$) was rejected. The coefficient was negative, implying that farms of less than 400 acres were less economically efficient than the moderate and larger-sized farms greater than 400 acres. The hypotheses of equal relative pricing efficiency for the two variable input categories also were both rejected.

The influence of land tenure on efficiency also was examined. The test followed the method outlined by Trosper. Let the variable T be gross income from land which is owned on each farm divided by total gross income from all land operated on that farm. The value of T can range from 0 to 1. The smaller the value of T, the greater the dependence on rented land. Following Trosper, we assume that the technical constants, β_{*i}, of the profit function for larger and smaller farms (i equals L for larger farms and s for smaller farms) are related to T as follows:

$$\beta_{*i} = C_{*i}^{cT}, \tag{4}$$

Where C_{*i} is the technical constant of the profit function for each group after correction for land tenure. The appropriate model (Model II) for estimating the impact of tenure then becomes

$$\begin{aligned} \text{Ln}\Pi = {} & \text{Ln}\beta_0 + cT + \beta'_1 D_s + \beta_2 \text{Ln} W \\ & + \beta_3 \text{Ln} CE + \beta_4 \text{Ln} LS + \beta_5 \text{Ln} FC \\ & + \beta_6 \text{Ln} AC + \beta_7 \text{Ln} PRODY + \beta_8 \text{Ln} BA/CA \\ & + \sum_{k=1}^{5} \alpha_k RD_k + e_5, \end{aligned} \tag{5}$$

and equations (2) and (3); where

$$\beta'_1 = \text{Ln}(\beta_{*L}/\beta_{*s}).$$

The estimated coefficients and related hypothesis tests of pricing and economic efficiency when land tenure is considered are presented in tables 2 and 3 as Model II.[2] The magnitude of the coefficients and estimated test statistics change only slightly.[3] The negative sign of the coefficient on the tenure variable indicates that variable profits decrease as the proportion of owned land increases. Test 10 of table 3, that $c = 0$, is rejected, further substantiating this relationship. Because of the intense competition for rental acreage and the major reliance on crop-share rental arrangements in this region, tenant farmers may be forced to strive for greater short-run profits on rental land. The long-run social consequences of such decisions may not be advantageous on land which is susceptible to erosion.

Summary and Implications

The results of this analysis suggest that for cash grain farms in Illinois, larger operations are no more economically efficient than moderate-sized farms.

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[2] Two observations were deleted from Model II because of data inadequacies relative to tenure.

[3] The t-ratio under the null hypothesis of constant returns to scale is $-.954$. This hypothesis at the 5% level could not be rejected.

This indicates that farm expansion which proceeds beyond the size which can be efficiently operated with twelve to eighteen months of labor will not result in efficiency gains which can be transferred to consumers. An alternative view of these results is that firm growth to a larger size category, which may generate additional income for the farm operator, apparently comes at no loss in economic efficiency to society in general.

The importance of land tenure on short-run, profit-maximizing behavior was also evaluated. Tenure appears to be an important factor in determining short-run profitability. For the sample analyzed, the degree of land ownership by the operator was found to be inversely related to short-run profit maximization.

The results of this analysis are not necessarily representative of U.S. agriculture or even Illinois crop farming in general. Rather, they are an attempt to evaluate the efficiency characteristics of a sample of farming operations for two important structural dimensions, farm size and tenancy. Because the basic data are drawn from farmers in a record system, the efficiency differences (or similarities) found for this sample are likely to be directly related to the two structural dimensions.

The findings of this research raise several interesting issues. In light of increasing concentration in the farm sector, the result that larger farms are no more economically efficient than moderate-size farms appears contradictory. An intriguing explanation involves the homogeneity of the sample's management input. Participation in management services may permit all farmers regardless of size to act as efficiently in the short run. If so, additional extension and management programs which facilitate producer decision making may have an appreciable impact on the structure of U.S. agriculture. Alternatively, the current secular movement toward larger operations may be influenced by the ability to market output, pecuniary economies of size on input purchases, credit and financial constraints, and changing technology over time more than short-run productive efficiency.

The finding that increasing the degree of rental acreage results in enhanced short-run profitability calls into question the "conventional widsom" of superior efficiency of the owner-operated farm (Rodefeld). Of course, tenancy has a long history in the cash grain-producing areas of Illinois and the bulk of farmers in this sample probably would own at least part of the land in their farming operation. Further research on this question, on the differences between FBFM farms and the entire population of midwestern farms, to isolate the factors affecting productive efficiency and on the relationship between the short-run and dynamic aspects of the structural problem seems warranted.

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Analysis of Fringe Benefits for Nonmetropolitan versus Metropolitan Employee Compensation

Helen H. Jensen

There has been little empirical research on nonagricultural labor markets and compensation practices of firms located in nonmetropolitan areas. To a large extent the research on nonmetropolitan areas has focused on the farm and hired labor market in rural areas (Bryant, Bawden, Saupe). In part the lack of empirical research reflects the historical importance of the agricultural sector, and in part it reflects the relatively recent expansion of nonfarm employment in nonmetropolitan areas. A notable exception was the 1973 study of rural industrial development and labor markets conducted by the Center for the Study of Human Resources of the University of Texas (Marshall, Till). Increasingly, even farm families are depending on employment in the nonfarm sector (Jordan and Hady).

Despite industrialization, nonmetropolitan wages remain below national industrial wages (Tweeten and Brinkman). Both Marshall's study and another study of four southern counties by Rungeling et al. find that employment is concentrated in relatively low-paying sectors. Both studies note that fringe benefits offered by rural employers are lower. Rungeling et al. conclude that "the lack of fringe benefits is due no doubt to the almost total absence of unionism in these counties" (p. 36). The following study of national compensation practices in metropolitan and nonmetropolitan firms analyzes the differences between the two areas' labor practices. While differences persist in the national data, factors in addition to unionism affect the level of fringe benefits.

Total compensation paid for labor services consists of both money wages and fringe benefits. Most fringe benefits, such as paid leave, expenditures for social security and other retirement programs, unemployment benefit programs, and employer's contribution to group life, accident, and health policies, can be measured directly as a monetary payment and represent an increasingly important part of compensation. In 1966, they were 15.4% of total compensation; by 1974, 20.1% (U.S. Department of Labor).

The shift toward fringe benefits reflects underlying factors which have encouraged nonwage relative to wage compensation, such as the untaxed status of the employer's contribution and an increased awareness of the possibilities for nonwage compensation. Employer-provided insurance provides a good example of nonwage compensation, as its use is widespread though subject to considerable variation. The employer contributions to two other major types of fringe benefits, social security and unemployment insurance contributions, are fixed by law.

The 1974 Bureau of Labor Statistics' Employer Expenditures for Employee Compensation Survey (EEEC) shows most metropolitan and nonmetropolitan establishments provided insurance coverage to employees. Eighty-nine percent of metropolitan establishments and 87% of nonmetropolitan establishments reported some type of health, accident, or life insurance payment. The level of employer-paid insurance varied considerably, though, with an average level of $343 per employee paid in metropolitan establishments and only $269 paid in nonmetropolitan ones. The underlying differences are important for understanding the changes which are occurring in nonmetropolitan labor markets.

Wage and Nonwage Compensation

While workers may be able to substitute between money and nonmoney wages and evaluate total compensation, studies have shown workers to be relatively uninformed about obtaining, or even accurately valuing, the nonwage component (Mabry). In general, the observed level of fringe benefits of workers in a firm depends on both employer and employee characteristics and may be represented as

$$B_i = f(\mathbf{X}_{1i}\ \mathbf{X}_{2i}),$$

where B_i is the level of fringe benefits in firm i, $\mathbf{X}_{1i}$ a vector of variables representing characteristics of the firm, and $\mathbf{X}_{2i}$ a vector of variables representing characteristics of the employees within the firm.

Previous study of fringe benefits has focused on determining the influence of the level of earnings, firm size, unions, and worker preferences. As expected, earnings, firm size, and unions have a posi-

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tive effect on the level of expenditures for fringe benefits within a firm (Bailey and Schwenck, Goldstein and Pauly, Oi). On the other hand, studies based on surveys of workers indicate that demographic and attitude toward work variables are more important in determining the preferences for the level of fringe benefits than strict maximization of the total economic return from work would indicate (Lester, Farber).

Stable differences in earnings persist across geographically different labor markets, but the structural aspects of labor markets' operation are not well explained (Hanushek). That metropolitan and nonmetropolitan labor markets differ is consistent with the arguments of labor institutionalists of the 1950s who argued that structural differences in a labor market affect the level (and type) of compensation. Dunlop (p. 17) argues that common wage-making characteristics are determined within "contours"—a stable group of firms which have (*a*) similar product markets, (*b*) similar source of labor, or (*c*) a common labor market organization. Certainly restricted (i.e., "costly") labor mobility between metropolitan and nonmetropolitan areas and a more homogenous nonmetropolitan labor force would foster the development of a more similar wage structure in nonmetropolitan areas.

Empirical Analysis of Employer-Provided Insurance

The 1974 EEEC survey provides information on employment and various forms of compensation for 4,417 establishments in nonagricultural, private industries. The survey has been conducted biennially from 1966 to 1976 and in 1977 and is the largest national survey of compensation practices. The 1974 data were the most recently available at the time of this study. Although the EEEC survey covered the private, nonfarm sector, a few agricultural firms were included. The survey identifies information based on the location of the individual establishment—not the corporate headquarters. Estimation of the compensation model uses these data for an analysis of differences between metropolitan and nonmetropolitan establishments in the amount of employer-provided payments for insurance.

In the 1974 survey, 28% of the firms were located in nonmetropolitan areas. The mean pay in metropolitan establishments was $9,467 with an average firm size of 697 employees, while in nonmetropolitan firms, the mean pay was $7,645 with an average firm size of 361 employees (including a few very large textile and other manufacturing firms).

The dependent variable is the amount of employer expenditures for combined life, accident and health insurance per employee. This itself is not a complete measure of the amount of insurance protection purchased by employees, directly or indirectly through employers, though it does indicate the level of employer contribution to fringe benefits.

Cost differentials in providing insurance between metropolitan and nonmetropolitan firms may appear either in the price charged for a given level of insurance or in the actuarial ("fair") value of insurance. The variation in the price is reflected by the size of firm. The larger the firm, hence group, the greater the discount because of the lower marketing and administrative costs of the larger group purchase. Variations in costs stemming from differences in accident rates, life expectancy, or health care costs are accounted for by type of industry, organization, and occupation. Lower expected losses would lower the cost of providing an equal amount of insurance. Lower costs of medical care do prevail in nonmetropolitan areas, though in addition, employers generally provide less comprehensive insurance (Rungeling et al.). Thus, lower levels of employer-paid insurance reflect both lower cost and less comprehensive fringe benefits.

Explanatory variables include both those related to establishment characteristics and those related to employee characteristics. All data were reported separately for the two types of employees: office workers and non-office workers. The types of industry and geographic region in which the firm is located are represented by a set of binary variables: the reference (omitted) industry is manufacturing; the reference region is the North Central region. The firm size is measured by the reported average number of full time employees during the year. The degree of unionization is represented by a binary variable equal to 1 where over 50% of the employees were covered by a collective bargaining agreement, 0 otherwise. The average pay for an employee is calculated by dividing the gross payroll by the number of employees.

A set of interactions between the type of industry and union status permit picking up the joint effect of the type of industry and the degree of unionization. Historically, unions have been more important in some industries than others. The omitted group is manufacturing establishments that are not covered by collective bargaining.

Ordinary least squares estimations of fringe benefit compensation for establishments in each of the two locations were compared using an F-test on the equality of the two regression equations (Kmenta, p. 373–4). The results from the analysis of the office and nonoffice workers within a firm appear in table 1. Significant differences between the metropolitan and nonmetropolitan level of fringe benefits per employee appear consistently in the analysis at the .01 level of significance and indicate that the two areas should be examined separately. Establishments in the South, both in metropolitan and nonmetropolitan areas, provide fewer fringe benefits.

Industry

Historically, some industries have provided more fringe benefits than others: manufacturing industries relatively more; construction, agriculture, and

Table 1. Nonwage Compensation of Office and Nonoffice Workers

	Office Workers		Nonoffice Workers	
Variable	Nonmetropolitan	Metropolitan	Nonmetropolitan	Metropolitan
Constant	−62.84	96.06**[d]	−3.40	−84.62**
Industry:[a]				
Agriculture	71.47	−327.61**	−124.80	−184.60*
Mining	197.07**	−66.62	−133.94**	−58.06
Construction	−25.01	−1.25	−157.85**	−111.75**
Transportation	36.87	−76.64**	−4.41	−40.46
Wholesale trade	−66.16	−62.03**	−42.36	−1.43
Retail trade	66.34*	125.78**	−46.81**	−40.87**
Finance, insurance	42.30*	−96.91**	26.41	21.47
Services	−72.49**	−181.30**	−36.41	−67.59**
Region:[b]				
South	−96.92**	−85.81**	−30.37**	−61.47**
Northeast	.36	−20.72	−5.44	−42.79**
West	24.52	−12.04	.85	−14.09
Employees	.1095**	.0463**	.0439**	.0394**
Employees^2 (000)	−.0150**	−.0022**	−.0061**	−.0021**
Mean Pay (000)	49.12**	36.73**	20.73**	49.51**
Mean Pay^2 (000)	−.00080**	−.00039**	−.00016**	−.00016
Union[c]	190.03**	29.64	160.49**	190.70**
Agric. × union	0.00	0.00	78.27	0.00
Mining × union	0.00	0.00	258.43**	71.16
Construct × union	−11.48	0.00	−29.53	76.31*
Transport × union	−17.89	93.52	56.12	−81.29*
Wholesale × union	−36.66	64.60	86.84	−48.09
Retail × union	−23.84	−70.28	−95.43	−87.81**
Finance × union	0.00	76.61	0.00	−122.62
Service × union	−88.10	235.39	−78.86	−123.45**
Adjusted R^2	.34	.32	.62	.63
N	1,098	2,952	1,007	2,421
	$F_{25,4365}$ = 2.62**		$F_{25,4365}$ = 2.19**	

Note: Dependent variable is employer-paid expenditures for life, accident, and health insurance per employee.

[a] Reference industry is manufacturing.

[b] Reference region is North Central.

[c] Reference union status is *not* under collective bargaining.

[d] Asterisks denote: *significant at the .05 level **significant at the .01 level.

nonprofessional service industries relatively less. This is supported in the analysis, though some location differences do exist. In general, firms in manufacturing industries provide more fringe benefits, particularly for nonoffice workers. Till, in his study of industries located in the nonmetropolitan South, found that manufacturing industries led others in their increases to employment in nonmetropolitan areas between 1959 and 1969. Within the manufacturing sector, there were shifts toward employment in industries which manufacture electrical machinery, transportation equipment, primary metals, petroleum and coal products, and rubber and plastic products. In a more detailed analysis of the EEEC data than is presented here, all of these industries (except electrical machinery) led other manufacturing industries located in nonmetropolitan areas in the level of fringe benefits provided in 1974.

Historically, the construction industry has had relatively lower fringe benefits because of seasonal work and lack of organization. Nonmetropolitan construction establishments do even more short-term and less regular contract work than others do. They provide less nonwage compensation.

The relatively higher nonwage compensation of service industries in nonmetropolitan is consistent with more similar practices in the homogenous nonmetropolitan labor markets. That is, the level of fringe benefits is determined with reference to all other industries in the more cohesive "contour" of the nonmetropolitan labor market.

Unions

The effect of unions on employer-paid contributions is large and positive, with the exception of metropolitan office workers, as has been noted in other studies (Kalachek and Raines, Solnick). Union members prefer more fringe benefits based on the demands of the older, more risk-averse union leaders (Farber).

Among non-office workers, the specific industry has a significant impact on the effectiveness of unions in determining the level of employer-paid benefits as indicated by significant industry union interaction. In all cases except unions in the metropolitan service industry, the net effect of unions on the level of benefits is positive. For metropolitan workers, the manufacturing and construction unions are particularly successful in gaining higher payments. In nonmetropolitan areas only unions in mining establishments have a significantly greater, and large, positive effect on the level of insurance benefits, compared to others including manufacturing. Although being in the mining industry per se has a negative effect for nonoffice workers, after accounting for the strong positive effect of the unions within mining (union plus interaction) the net effect within the mining industry in nonmetropolitan areas on fringe benefits is positive (−$133.94 + 160.49 + 258.43 = $284.98), as expected. The employer-provided health benefits are uniquely important in the mining industry.

Firm Size

The size of the firm has a significant and positive effect (though at a decreasing rate) on the level of fringe benefits. The consistency of the finding indicates that nonmetropolitan firms participate in the same market advantages that metropolitan firms do in obtaining group discounts.

Level of Money Wages

Higher paid employees have more insurance provided because they have both higher costs associated with turnover (Oi) and also higher marginal tax rates on wages. The consistently positive, though nonlinear, effect of income on insurance payments supports this for all employee groups. Again, there are location differences, especially for nonoffice workers. The EEEC data show average mean pay to be lower in nonmetropolitan firms. Martin also notes that rural money wages tend to be lower than urban wages for the same job and skill level. However, real wages are more equal, to the extent that wage differences represent lower cost of living or compensation for other amenities in nonmetropolitan areas. At a given money wage, nonoffice workers in nonmetropolitan areas receive lower fringe benefits than do those in metropolitan ones, indicating cost of living differences do not explain all of the differences. This is not true for office workers, where there is little difference in the effect of pay on the level of benefits. Hanushek also found between labor market variation in wages (both for SMSAs and non-SMSAs) to be smaller for college-educated workers. Both sets of results are consistent with the more educated workers' being in a national, more mobile labor market.

Summary and Conclusions

The analysis of the nonwage compensation practices of establishments supports the proposed model of nonwage compensation which accounts for firm as well as employee characteristics. Although the data do not permit greater insight into the microadjustments of workers, they do provide evidence that the employment markets in nonmetropolitan and metropolitan areas differ. The ability to explain nonwage compensation is better for nonoffice workers than for office workers. As expected, the size of the establishment, manufacturing industry, the existence of union bargaining, and the level of wages all have a positive effect on the level of employer-provided insurance. Southern location has a negative effect.

The underlying differences between the employment compensation practices in nonmetropolitan and metropolitan areas provide evidence that the two labor markets are significantly different. While it is interesting to note the unique effects of specific industries in nonmetropolitan industries such as mining, in general, differences between the two areas are consistent with a more homogenous labor market in the nonmetropolitan areas. To the extent we are observing a labor market contour, we would expect to see the nonmetropolitan areas continue to lag behind the average level of nonwage compensation provided in metropolitan areas.

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Predicting the Direct Benefits of a Food Price-Reporting or Preference-Changing Program

W. H. Lesser and W. K. Bryant

Along with the sharp retail food price increases of 1972 came substantial public pressure to "do something" about them. The public perception appeared to be that the food industries, particularly the food retailers, were largely to blame. Possibly in response to this pressure, several government-sponsored investigations of the food-retailing industry were begun, e.g., Joint Economic Committee, Council on Wage and Price Stability. These studies may have contributed to a long-term stabilization or reduction in retail margins (see Mueller), but the immediate effects were negligible. Thus, interest persists in finding some other approach to help constrain retail food prices.

An experiment conducted by Devine in Ottawa, Canada, in 1974 and 1975 suggested a possible course of action. This experimental public reporting of retail food prices was credited, among other things, with increasing consumer surplus by an estimated $900,000 per month. This resulted in a benefit to society of $8,834 per month, after adjusting for losses to retailers (Devine and Marion 1979, p. 235). These benefits are based on the aggregated indirect effects of price reporting—the area-wide decline in average food prices associated with interstore competition spurred by improved price information. However, further savings will be realized by shoppers who switch from relatively high to relatively low priced stores as a result of improved price information. These are referred to as the direct effects of price reporting.

The report on the Ottawa study and subsequent replications of that experiment in the United States and Canada gave little attention to the direct effects (e.g., Uhl, Boynton, Blake). Consequently, this study focuses on direct effects. In particular, we attempt to develop a simple and low-cost method for estimating, a priori, the direct effects of a price-reporting program in a particular market area. This method is then used to estimate the effects of altering consumers' store selection criteria as price versus nonprice factors are emphasized.

There are two principal reasons why an a priori estimate of expected direct savings is of interest. First, where resources for operating price-reporting programs are scarce, the estimated direct savings can be used to rank market areas. Those with the higher estimated direct payoffs would be preferred for reporting programs. Ideally, area selection decisions also consider expected indirect savings. To date this has not been possible. The effects on average food prices of price reporting during the experiments has been highly variable, and causal factors were incompletely explained (Uhl, Boynton, Blake, pp. 62–95). On the other hand, the direct effects have been found to be generally unaffected by price reporting. Uhl, Boynton, and Blake, in a study of four experimental price-reporting projects, found no significant effect on the level of price dispersions (pp. 3–35). Devine and Marion did report a substantial decline in dispersion in Ottawa, but there remains a question about how the results ought to be interpreted (1979, pp. 228–29; 1980, pp. 269; Lesser and Bryant, p. 268). The predictive value of the method discussed here nevertheless depends on the assumption that retailers will maintain relative price spreads following price reporting. While this assumption seems adequate if only a small, say 10%, portion of shoppers is informed, the effects of broader based programs remain uncertain until more definitive research results are available.

Additionally, an estimate of the direct effects of price reporting would be of interest to groups who might consider a nonpublic information program. Such groups could include church organizations, homemakers' organizations, program aides working with low income families, or even cable television subscribers. Where groups are small enough so that no store response is expected among retailers, the direct benefits to the participants approximates the total gross returns of the reporting program.

Another approach to lowering consumers' food expenditures is to enhance their price consciousness in store selection. This might be particularly appropriate for lower income families who underestimate the potential long-term savings from careful price conscious shopping. Such programs could be part of the Expanded Food and Nutrition Education Program (EFNEP) or of comparable public or private efforts. The method developed in this paper also might be used to determine expected benefits from these educational programs.

The method involves two steps (*a*) identifying the lower price store(s) in a market area and (*b*) deter-

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mining consumers' awareness of relative store prices and their store selection criteria. Shoppers were classified as informed or uninformed based on their knowledge of relative costliness among stores, and as price, convenience, or amenity shoppers, based on their stated store selection criteria. Conditional probabilities based on *ex ante* behavior were used to project price-reporting responses. The procedures were developed through a pilot example with data from Ithaca, New York. Ithaca is a relatively small community and the major shopping center for a generally rural area with a 1979 county population of 22,500 households (Larson, table 36).

Because of funding limitations pragmatic considerations rather than strict statistical sample design procedures guided data collection. Two sample-related factors are particularly noteworthy. First, the basket of items used to determine the relative costliness of area food stores contained twenty-six items most commonly purchased by low to middle income shoppers, including seven meat items and relatively few dry goods.[1] This basket differs in size and composition from those used by Devine and Marion (1979) and Uhl, Boynton, and Blake. This may result in a different ranking of stores compared to rankings based on a larger market basket with a smaller share of meat items. Second, the consumer survey was conducted five months after the price survey. For the results to be valid, it is necessary to assume that relative store price rankings observed in summer 1978 remained constant through early 1979.

Two data sets were collected in the study area during 1978 and 1979. Relative store costliness rankings were developed from data on the twenty-six basket items collected from seven stores for twelve weeks during the summer of 1978. These prices were adjusted using consumer price index weights. A weighted market basket price was compiled. Four chains operated multiple outlets in Ithaca. All branches of these chains were assumed to charge the same price for identical items. Several spot checks could not contradict this assumption. Random telephone interviews were used to collect data about consumers' knowledge of the relative costliness of area stores and about their store selection criteria. A total of 127 questionnaires were completed during January 1979. Only interviews with the major food shopper of households who shopped predominately in the Ithaca area were used.

Estimating the Direct Effects of Price-Reporting and Preference-Changing Programs

A plot of weighted market basket prices revealed that two stores, identified as C and D, were with only three exceptions the lowest priced in Ithaca for the weighted basket. In the subsequent analysis stores C and D are identified as the low or lowest priced stores.

During the telephone survey, respondents were asked to (*a*) identify the store(s) they believed had the lowest overall prices for the items they buy, (*b*) list the store(s) they shopped at regularly, (*c*) identify the reasons they shop at those store(s), and (*d*) provide their residence location and shopping travel route. These answers provided information about whether consumers (*a*) shopped at either of the two lowest priced stores, C and D, (*b*) could identify the lowest priced stores in the Ithaca market, (*c*) identified price, convenience or amenity factors as paramount in their store selection, and (*d*) lived as close or closer to the low priced stores than the others.

Each respondent was classified into one of six categories according to the following criteria. Shoppers who identified stores C and D as being low priced were classified as informed (I); others are considered uninformed ($\bar{I}$). Those who mentioned a price-related factor ("saves money," "good prices," "ads," "specials") either first or second when describing why they selected their regular store(s) were classified as price shoppers (PS). Shoppers mentioning convenience ("close," "convenient," "habit") or amenities ("good quality," "variety," "good deli," "nice cashiers") as the first two selection reasons were classified as nonprice shoppers ($\overline{PS}$). Finally, shoppers were classified as living "close" to a low priced store if stores C or D were located near their residences.

Table 1 presents the results of the consumer survey for the 127 completed questionnaires. Shoppers were classified according to where they shop, their level of price information, their store selection criteria, and their residence location. The data are presented as both frequencies and conditional probabilities. The frequencies may be used to determine, for instance, what portion of shoppers do not regularly patronize the low priced stores (59/127 = 46.5%). Conditional probabilities, on the other hand, estimate the likelihood that an informed price shopper will shop at the lowest priced store as $Pr[LP/I, PS] = .81$. Here Pr refers to the probability of the event to the left of the slash occurring given that the conditions on the right hold. This allows estimation of the change in the probabilities of shopping at the lowest price stores given changes in information and price preferences, holding other factors constant. If a price shopper becomes informed via a price publication program, then the probability that he or she will shop at the lowest price store will increase by $.95 - 0.0 = .95$ if he/she lives close to a low price store and by $.71 - 0.0 = .71$ if not. However, if an uninformed, nonprice shopper becomes informed through a price publication program, the probability that he or she will shop at a low-price store will increase by $.71 - .1 = .61$ if he/she lives close to a low priced store and by

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[1] Items included in the market basket are: round roast, sirloin steak, chuck steak, pork chops, hamburger, chicken, hot dogs, eggs, milk, margarine, cheese, tuna fish, carrots, peas, Coca-Cola, frozen orange juice, sugar, flour, coffee, spaghetti, rice, corn flakes, cooking oil, powdered milk, white bread, and bananas.

Table 1. Frequencies and Conditional Probabilities of Shopping at Lowest Priced Stores

	Frequencies									Conditional Probabilities								
	Informed (I)				Uninformed ($\overline{I}$)				Total	Informed (I)				Uninformed ($\overline{I}$)				Total
	PS		$\overline{PS}$		PS		$\overline{PS}$			PS		$\overline{PS}$		PS		$\overline{PS}$		
	CLP	$\overline{CLP}$	CLP	$\overline{CLP}$	CLP	$\overline{CLP}$	CLP	$\overline{CLP}$		CLP	$\overline{CLP}$	CLP	$\overline{CLP}$	CLP	$\overline{CLP}$	CLP	$\overline{CLP}$	
Shops at lowest priced stores (LP)	18	17	15	17	0	0	1	0	68	.95	.71	.75	.50	0.0	0.0	.1	0.0	.54
	35		32		0		1			.81		.60		0.0		.05		
	67				1					.69				.3				
Does not shop at lowest priced stores ($\overline{LP}$)	1	7	5	17	6	5	9	9	59	.05	.29	.29	.50	1.0	1.0	.9	1.0	.46
	8		22		11		18			.19		.40		1.0		.95		
	30				29					.31				.97				
Total	97				30				127									1.00

Key: *PS*, price shopper; $\overline{PS}$, not price shopper; *CLP*, lives close to lowest price stores; $\overline{CLP}$, does not live close to lowest price stores.
Note: 127 respondents, Ithaca, New York, 1979.

.50 − 0.0 = .50 if not. As one would expect, the responsiveness to an information program is strongly related to consumer preferences about low prices in relation to other store attributes, and to residence location.

Estimating Effects of Improved Information

An important application of conditional probabilities is to estimate market shares of the lowest priced stores and how they might change. This is possible given the random nature of the sample which, in the absence of response bias, gives an unbiased estimate of the market share of the lowest price stores. The low priced stores have a market share of 68/127 = 53.5% of all area shoppers. A price publication program can be expected to have the greatest effect on the 46.5% of all shoppers who currently do not use the low priced stores. Of these consumers, 49% (29/59) are classified as uninformed. It is to this 23% (29/127) of all consumers in this market that a price publication program would be principally directed.

Assuming that, once informed, the currently misinformed price shoppers would behave like the currently informed price shoppers, and the currently uninformed nonprice shoppers would behave like the currently informed nonprice shoppers, then 6(.95) + 5(.71) + 9(.75) + 9(.50) = 20.5 sample consumers might be expected to switch to the lowest price stores as a result of a price information program. This implies the market share of the lowest price stores would increase from a preprogram 53.5% to a post program (68 + 20.5)/127 = 70%, an increase of 16.5 percentage points or 31%. A minimum estimate of changes in shopping patterns following price reporting would be to assume that once informed, only the uninformed shoppers who live closest to a low-price store would behave like informed shoppers. Under this assumption, 6(.95) = 5.7 sample consumers would shift to the lowest price stores. Then the lowest priced stores' share would increase to (68 + 5.7)/127 = 58%, a positive change of 4.5 percentage points or an 8.4% increase.

There are several reasons why these estimates might miss the true value. First, these results are based on an assumption of 100% efficacy in the price publication program. That is, all previously uninformed shoppers are reached and their perceptions are changed. This is extremely unlikely for a public-reporting program because not all shoppers read local newspapers, watch local TV stations or listen to local radio programs. In practice, Uhl, Boynton, and Blake found that 38% of the shoppers were aware of an experimental newspaper price reporting program run for six to twelve weeks in eight cities (p. 110). In Buffalo, New York, only 20% of area shoppers were aware of a retail food price range-reporting program that had been published in the major newspaper for seven years (Lesser). Of course if a price-reporting program were conducted within a small group, all participants would likely be informed.

Second, it is possible some shoppers incorrectly perceive interstore price differences to be greater than the true value. Once informed, they would shift from the low priced store to a higher priced store which offers lower shopping costs and/or greater satisfaction. This could be called "reverse flow" due to price reporting. This effect is difficult to measure although it could include the entire share of the low priced stores. A likely subgroup for this reverse flow would be informed, nonprice shoppers not living close to the low priced stores, or, from table 1, 17/127 = 13% of all shoppers.

Third, and of greater consequence, is the possible misclassification of price shoppers as nonprice shoppers. This would happen if shoppers wrongly thought that all or most stores charge essentially the same prices for their market basket. This group may then have responded to our store selection question by mentioning convenience or amenity rather than price. As a result, following price reporting, these latent price shoppers could act like informed price shoppers rather than informed nonprice shoppers. Thus the post information probability of shopping at a low priced store would increase from $Pr(LP/I, \overline{PS}) = .60$ to $Pr(LP/I, PS) = .81$, which is an increase of .21. There are several reasons to expect that this effect would not be large. Our sample displays a relatively large number of price conscious shoppers (43 + 11)/127 = 42.5%, table 1. This is substantially greater than the proportion of predominantly price conscious shoppers observed in other studies (Skinner, Market Facts).

Finally, the lowest priced stores were identified using a specific food basket. Since baskets and weights differ among shoppers, some fraction of shoppers may be improperly classified. Measuring the extent of misclassification would require comparing store rankings over a range of baskets and weights. This goes beyond the scope of the current study.

Assuming the points above are insignificant and the retailers' response to price reporting does not change the price dispersions, the maximum direct savings to shoppers from a price-reporting program in Ithaca can be estimated using

$$HS = \Sigma_i \Delta Pr_i (P_i - \bar{P}_{c,d}),$$

where HS is savings per household per weekly shopping trip; i is higher priced stores, A, B, E, F, and G; ΔPr_i, change in probability of shopping at store i following a price information program; P_i, unweighted market basket price in store i; $\bar{P}_{c,d}$, market basket price of stores C and D weighted by market share. If one week during the study period (27 July 1978) represents average weekly savings between stores, then HS = .111($1.40) + .136 ($1.13) + .138 ($−.35) + .079($.49) + .071($2.09) = $.4479. Expected savings are nearly 45¢ per household per week giving estimated weekly savings for the Ithaca market area of $10,000, or $500,000 annually. This estimate should be adjusted to reflect the portion of shoppers whose habits are changed by the program. The assumption that retailers' responses will not affect the spread among stores is potentially a strong one, but it is in agreement with much of the available empirical evidence.

Estimating Effects of Preference Changing

A further use of the conditional probabilities is to estimate the ability of educational programs to shift preferences away from other store attributes and toward low price. For uninformed nonprice shoppers who remain uninformed but become price shoppers, the probability of shopping at the lowest price stores would either decline or not change (−.1 or 0.0). In contrast, if informed nonprice shoppers become price shoppers in response to a preference shifting program, the probability would increase by .95 − .75 = .20 and by .71 − .50 = .21, respectively (depending on residence location). By changing preferences uninformed shoppers might search more, becoming informed over time. However, the comparison between a preference-shifting program and a price information program is clear and expected; a program which actually improves consumers' price information is a more effective program even though the programs overlap.

Conclusions

A simple and low-cost method has been introduced for estimating *ex ante* the direct effects of a retail food price-reporting program and a store selection preference-changing program. The procedure is purposely simple so that groups interested in applying it may do so without prior analytical experience or access to electronic data-processing equipment. This process should be used in conjunction with other information such as concentration data on retail food stores in the study area, price spreads among stores, capacity utilization in the lower priced stores, and ease of access to these stores. In larger areas, where some stores are distant from many shoppers, relevant subshopping areas must be identified and analysis focused there.

The application of this method to data from Ithaca, New York, gives some interesting and reasonable results even though there were several sample size and timing limitations. Further applications will be required to verify the ultimate usefulness of this procedure.

Our results illustrate that programs for increasing information are preferable to programs for changing preferences. In fact, if improved price information changes latent price-conscious shoppers into active ones, then the preference for a price-reporting program is even stronger.

We estimate that a price publication program will increase the market shares of identified low-priced stores by 4.5 to 16.5 percentage points, depending on residence location. This estimate does not take into account that (*a*) the program will not inform 100% of area shoppers, (*b*) some shoppers may rationally switch from low- to high-priced stores, (*c*) some shoppers may be improperly classified as nonprice conscious shoppers and (*d*) differences in individual shoppers' baskets and weights may have caused them to be misclassified. Point (*d*) is difficult to measure, while (*b*) and (*c*) lead to apparently modest changes in opposite directions.

Our results suggest that, even in areas like Ithaca where many shoppers appear adequately informed, the potential gross direct payoff to a price-reporting program is rather large. Additional savings may occur via a general decline in area-wide food prices unless the price reports contribute to collusion rather than competition. Further substantiation is required before strong reliance can be placed on these results. In addition, further research is needed to better understand shopper uses of and responses to price information. Of particular relevance is analysis of store selection criteria and the interaction between information and store selection. These are tasks for economists. For local groups interested in price reporting, the method presented here may make it easier to estimate the payoff to a program, particularly a program geared to individuals whose demand for and use of information is known.

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Engel Analysis with Lorenz and Concentration Curves

James R. Blaylock and David M. Smallwood

Economic analysis of income transfer programs requires knowledge of how households with different incomes alter expenditure patterns as their incomes change. Classical demand theory, however, provides little guidance for quantifying these income response parameters. Consequently, researchers have relied on statistical approaches to find functional forms which "best" describe the relationship between expenditures and income. The most commonly used specifications (linear, semilogarithmic, and double-logarithmic) imply that the Engel (expenditure) elasticities are monotonically increasing, decreasing, or constant across the income spectrum. However, serious errors may occur if actual elasticities do not adhere to one of these patterns.

This paper utilizes a nontraditional approach, based on income and expenditure distributions, to estimate expenditure elasticities. The method places less emphasis on the mathematical specification of the Engel relation and allows for increased flexibility in elasticity patterns. The primary purposes of this article are to examine household income and expenditure distributions in order to deduce the underlying Engel relationship and to measure inequality within each distribution. When other relevant factors (e.g., prices) are held constant, the expenditure distribution on a commodity is directly related to the income distribution via the commodity's Engel function.

A recently proposed technique for the estimation of Lorenz and concentration curves is employed (Kakwani and Podder). These curves are directly related to the cumulative distributions of income and expenditures. Expenditure elasticities and measures of income and expenditure inequality can be calculated from the estimated parameters of the Lorenz and concentration curves (Kakwani). Elasticities thus estimated are not constrained to be monotonic or constant across the income spectrum, and may vary across commodities.

Related objectives are to (*a*) introduce a generalized functional form to describe the Lorenz and concentration curves, (*b*) compare estimated expenditure elasticities among three urbanizations for several food groups using U.S. data, (*c*) examine elasticity patterns within each urbanization, and (*d*) examine inequality of food expenditure and income distributions for each urbanization.

Lorenz and Concentration Curves

The Lorenz curve relates the cumulative proportion of total income received to the cumulative proportion of population units, with units arranged by ascending level of income. Concentration curves relate the cumulative proportion of economic variables other than income to the cumulative proportion of the population.[1] Thus, other factors constant, the Lorenz and concentration curves are directly related to each other via the relationship between income and the economic variable of interest. For example, given the income distribution and the Engel function for a particular commodity, one can easily derive the expenditure distribution for the commodity. Likewise, given the concentration curve for expenditures on a commodity and the Lorenz curve, one can derive the implied Engel function. The derivation of this relationship, using elasticities, is the subject of this section.

Mathematically, Lorenz and concentration curves can be expressed conveniently in terms of the probability distribution function (PDF) and the first moment distribution function (FMDF) of income and expenditures, respectively. Assuming that per capita income, Y, is randomly distributed with probability density function $f(Y)$, and mean μ, then the PDF of income is defined as

$$(1) \qquad F(Y) = \int_0^Y f(y)dy$$

and represents the proportion of the population units having income less than or equal to Y. The FMDF of Y is defined as

$$(2) \qquad F_1(Y) = (1/\mu) \int_0^Y yf(y)dy$$

and represents the proportion of total income received by population units having total income less than or equal to Y.

The relationship between $F(Y)$ and $F_1(Y)$ is called the Lorenz curve. A typical Lorenz curve is *ABC* in figure 1. The segment *ADC*, defined by $F(Y) = F_1(Y)$, is called the egalitarian line and represents

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[1] This definition of concentration curves (Kakwani and Podder) differs from the traditional definition by requiring an ordering of the population units by income rather than the economic variable of interest.

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the special case of a uniform and equal income distribution across the population units. The extent to which the Lorenz curve deviates from the egalitarian line indicates the degree of income inequality.

A concentration curve is similar to a Lorenz curve. Assuming $v_i(Y)$ to be the implied but unknown Engel relation for the *i*th commodity and μ_i to be the expenditure mean, then the *FMDF* for expenditure on the *i*th commodity,

$$(3) \qquad F_1[v_i(Y)] = (1/\mu_i) \int_0^Y v_i(y) f(y) dy,$$

is the proportion of per capita expenditure on the commodity by population units having total income less than or equal to Y. The concentration curve for the *i*th commodity is defined by the relationship between $F(Y)$ and $F_1[v_i(Y)]$.

To facilitate estimation, coordinates of the Lorenz and concentration curves are redefined using a method outlined by Kakwani and Podder. This new coordinate system defines the curves in relation to the egalitarian line. Specifically, let B be any point on the Lorenz curve with coordinates $[F(Y), F_1(Y)]$ and define new coordinates,

$$(4) \quad \theta = [F(Y) + F_1(Y)]/\sqrt{2} \text{ and}$$
$$\Phi = [F(Y) - F_1(Y)]/\sqrt{2}.$$

Hence, θ represents the length of the line segment AD from the origin along the egalitarian line and Φ represents the length of the line segment BD from B to the egalitarian line. This coordinate system reflects a 45-degree clockwise rotation of figure 1.

The equation of the Lorenz curve in terms of Φ and θ can be written as

$$(5) \qquad \Phi = g(\theta),$$

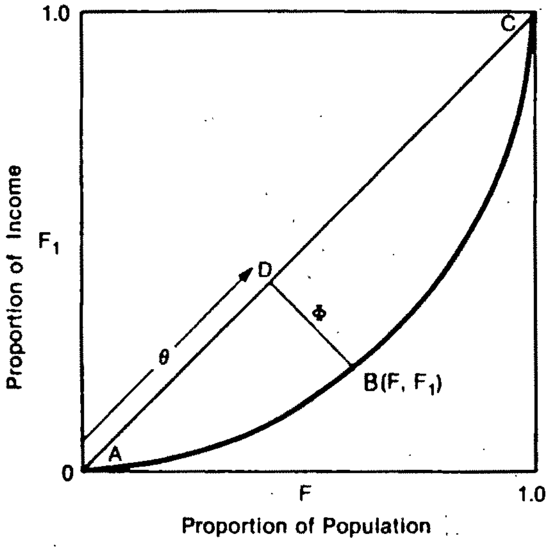

Figure 1. Lorenz curve

where θ varies from zero to $\sqrt{2}$. The first and second derivatives of Φ with respect to θ are

$$(6) \qquad g'(\theta) = (\mu - Y)/(\mu + Y) \text{ and}$$

$$(7) \qquad g''(\theta) = -(2\sqrt{2})\mu^2/[f(Y)(\mu + Y)^3].$$

The same coordinate transformation for the concentration curves is

$$(8) \qquad \theta_i = \{F(Y) + F_1[v_i(Y)]\}/\sqrt{2} \text{ and}$$
$$\Phi_i = \{F(Y) - F_1[v_i(Y)]\}/\sqrt{2}.$$

The general form of the concentration curve for the *i*th commodity in terms of the new coordinates is

$$(9) \qquad \Phi_i = g_i(\theta_i),$$

with first and second derivatives defined by

$$(10) \quad g'_i(\theta_i) = [\mu_i - v_i(Y)]/[\mu_i + v_i(Y)] \text{ and}$$

$$(11) \quad g''_i(\theta_i) = [-2/\sqrt{2}][\mu_i^2 v'_i(Y)]/ [f(Y)\{\mu_i + v_i(Y)\}^3].$$

The expenditure elasticity for the *i*th commodity is defined as

$$\eta_i = (\partial E_i/\partial Y)(Y/E_i),$$

where E_i is expenditure and Y denotes income. Using this definition and equations (6), (7), (10), and (11), the expenditure elasticity for the *i*th commodity (in terms of the Lorenz and concentration curves) is

$$(12) \quad \eta_i = \frac{\{g''_i(\theta_i)[1 + g'(\theta)]^2[(1 - g'(\theta)]\}}{\{g''(\theta)[1 + g'_i(\theta_i)]^2[1 - g'_i(\theta_i)]\}}.$$

If data on per capita expenditure for the *i*th commodity are grouped by income class, then equation (12) can be used to compute expenditure elasticities at the end points of each class (Kakwani). In this analysis the elasticities derived using the above procedures are conditioned on income and urbanization. The effect of other variables is assumed to be minimal. However, this kind of analysis can be extended to other possible determinants of food expenditures such as race or region by data disaggregation.

An additional benefit of this approach is that measures of income and expenditure inequality can be calculated conveniently using the estimated parameters of the Lorenz and concentration curves.

The most frequently used measure of inequality is the Gini coefficient. The Gini coefficient measures the departure of the Lorenz (or concentration) curve from the egalitarian line. It is the ratio of the area between the egalitarian line and the Lorenz (or concentration) curve and the total area under the egalitarian line. Since the area under the egalitarian line is ½, this ratio is equal to twice the area between the Lorenz curve and the egalitarian line. In terms of the translated coordinate system, the Gini coefficient for income (or expenditures) is

$$(13) \qquad GC = 2\int_0^{\sqrt{2}} g(\theta)d\theta.$$

The indices may vary between 0 and 1 for income and between -1 and 1 for expenditure. Negative Gini ratios result from negative expenditure elasticities; the concentration curve lies above the egalitarian line because expenditures are higher at lower incomes than at higher incomes. A Gini coefficient of zero indicates perfect equality of income (or expenditures). A coefficient of one (or minus one for expenditures) reveals total inequality. In this paper, the Gini coefficients are calculated using Simpson's rule for numerical integration.

Model Development

Equations of Lorenz and concentration curves have been derived traditionally from density functions of income and expenditure distributions, respectively, usually with poor results (Kakwani and Podder). The coordinate system illustrated in the previous section provides the basis for direct estimation of the Lorenz and concentration curves, once their mathematical form is specified. Then, from the estimated parameters of the Lorenz and concentration curves, corresponding expenditure elasticities and Gini coefficients can be calculated.

Kakwani and Podder propose a functional specification for describing relationships $g(\theta)$ and $g_i(\theta_i)$ based on a modified Beta function. The Box-Cox (B-C) model we propose includes the Kakwani and Podder (K-P) function as a special case and gives a better fit to the data (Box and Cox).

The K-P function for the Lorenz curve is

$$(14) \quad \ln(\Phi) = A + \alpha \ln(\theta) + \beta \ln(\sqrt{2} - \theta) + e,$$

where A, α, and β are parameters to be estimated and e is the equation error term. This general model also applies to concentration curves. Equation (14) can be estimated by ordinary least squares.

The Box-Cox transformation for any positive variable W is defined as

$$(15) \quad \begin{aligned} W^{(\gamma)} &= (W^{\gamma} - 1)/\gamma, \quad \gamma \neq 0 \\ &= \ln(W) \quad\quad , \quad \gamma \to 0, \end{aligned}$$

where γ is an unknown parameter. The model we propose for estimating the Lorenz curve is

$$(16) \quad \Phi^{(\lambda)} = A^* + \alpha^* \theta^{(\nu)} + \beta^* (\sqrt{2} - \theta)^{(\delta)} + u,$$

where λ, ν, δ, A^*, α^*, and β^* are parameters and u is the error term. Equation (16) asymptotically approaches the corresponding K-P function as all transformation parameters approach zero. Thus, the B-C function allows added flexibility in determining the appropriate degree of nonlinearity. The same functional specification as in equation (16) is used for estimating concentration curves.

Equation (16) is nonlinear in the parameters and is estimated via maximum likelihood techniques. The likelihood function, assuming a normally distributed error term with zero mean and constant variance, is

$$(17) \quad L = \prod_{j=1}^{N} [1/(2\pi\sigma^2)^{\frac{1}{2}}]^N \exp\{-(1/2\sigma^2)[\Phi_j^{(\lambda)} - A^* - \alpha^*\theta_j^{(\nu)} - \beta^*(\sqrt{2} - \theta_j)^{(\delta)}]^2\}|J|,$$

where $|J|$, the Jacobian of the inverse transformation from $\Phi_j^{(\lambda)}$ to Φ_j, is equal to $\prod_{j=1}^{N} \Phi_j^{\lambda-1}$ and the product, Π, is calculated over all observations, N. After logarithmic transformation of equation (17), consistent and asymptotically efficient estimates of the parameters can be obtained via a nonlinear maximum likelihood algorithm.[2] The likelihood functions of the concentration curves can be derived similarly.

Data

The 1972–74 Consumer Expenditure Diary Survey (CEDS), compiled by the Bureau of Labor Statistics, is the source of data for this analysis. Since the CEDS survey covered a period of rapidly rising food prices, only the first year of the survey was used in an attempt to lessen price effects. However, within each year, the survey sample is nationally representative. These data were obtained from a cross-section of U.S. households reporting detailed information on purchases during a two-week period together with socioeconomic data concerning the household units. Prior to this study, this data was extensively examined for reporting and coding errors and was edited into a convenient format (Buse, Mann, Salathe).

The CEDS sample was partitioned into three mutually exclusive and exhaustive urbanization categories. These three subgroups are defined as (*a*) SMSA—population of 50,000 or more; (*b*) URBAN—population of between 10,000–50,000; and (*c*) RURAL—population of less than 10,000. Separate analyses were performed on each urbanization category.

Annual income from all sources and weekly expenditures for food at home and away from home were used to analyze food expenditure/income distributional relationships. Income and expenditures are expressed on a per capita basis to adjust for differences in family size and then aggregated into population percentiles arranged by income.

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[2] Approximate asymptotic standard errors of the parameters from the B-C model are obtained from the negative of the inverse matrix containing the second partial derivatives of the likelihood function. The standard errors reported in this paper are approximate because it is not possible to compute the expected value of the elements in the information matrix. Hence, care should be taken in the interpretation of *t*-tests. The Davidon-Fletcher-Powell algorithm (see Powell) was used.

Empirical Results

Parameter estimates and approximate standard errors for both the K-P and B-C specifications of the transformed Lorenz and concentration curves are reported in table 1. Only the SMSA results are included.[3]

The likelihood ratio test is used to compare the K-P specification with the more flexible B-C extension. This test is appropriate since the two models are nested: the K-P function is a special case of the B-C model when λ, ν, and δ are zero. The test statistic, −2 times the logarithm of the likelihood ratio (defined as the ratio of the restricted [K-P] to the unrestricted [B-C] likelihood function), is asymptotically distributed as a chi-square random variable. Its degrees of freedom correspond to the number of independent parametric restrictions (three in this case) used to obtain the reduced or restricted model. Evaluation of the K-P and B-C functions involves comparing the calculated test statistics with tabulated values of the chi-square variable at the 0.01 significance level. The restricted specification is rejected for large values of the calculated test statistic.

The likelihood ratio test statistics are reported in table 2. The test results indicate that the B-C model provides a significant statistical improvement over the K-P model for all estimated Lorenz and concentration curves. Both the B-C and K-P models provide a good fit. However, the B-C model with its added flexibility performs better.

Expenditure elasticities by urbanization and income are presented graphically in figures 2 and 3 for the food-at-home and food-away-from-home categories.[4] Illustrated in these figures are some of the diverse elasticity relationships that this model is capable of producing. These relationships may be increasing, decreasing, relatively constant, or nonmonotonic across the income spectrum.

Elasticity patterns vary considerably across urbanizations and within each urbanization. The urban food-at-home elasticity increases up to about the $1,500 per capita income level and then monotonically declines. The rural and SMSA food-at-home elasticities increase gradually with income. The food-away-from-home elasticities for these two urbanizations increase monotonically but at a faster rate than the food-at-home elasticities. The food-away-from-home elasticities for the rural and SMSA groups are smaller across the entire income spectrum than the corresponding elasticities for the urban group. In general, it appears that urban and SMSA residents have a larger elasticity across the entire income spectrum for food away from home than do their rural counterparts. The opposite is true of food at home for per capita incomes of $3,000 or more. This may be influenced by location and travel considerations.

In summary, considerable variation exists in the way residents of different urbanizations (and at different income levels within a given urbanization) allocate additional dollars of income for food at home and food away from home.

The Gini coefficients as calculated from the actual observations and those estimated from the pa-

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[3] Parameter estimates for all models discussed in this paper and an analysis for nine major food groups are available from the authors.

[4] It is complex to calculate even approximate standard errors for elasticities in this highly nonlinear model. Hence, we do not test for statistical differences in elasticities across urbanizations.

Table 1. Estimated Parameters for K-P and B-C Models, SMSA

	Parameters						
Curve (K-P)	A	α	β	λ	ν	δ	Log-Likelihood Value
Lorenz	0.3755	0.8531	0.8508	0.0	0.0	0.0	628.83
	(0.0007)[a]	(0.0014)	(0.0019)				
Food at home	0.0607	0.8211	0.7087	0.0	0.0	0.0	603.89
	(0.0009)	(0.0125)	(0.0114)				
Food away from home	0.3418	0.9273	0.9210	0.0	0.0	0.0	511.33
	(0.0029)	(0.0064)	(0.0077)				
	Parameters						
Curve (B-C)	A^*	α^*	β^*	λ	ν	δ	
Lorenz	−1.2027	0.8894	0.9101	−0.1981	−0.2063	−0.1788	718.34
	(0.0616)	(0.0245)	(0.0265)	(0.0640)	(0.0510)	(0.0500)	
Food at home	−1.5367	0.3474	0.3017	0.4410	0.4400	0.3509	610.49
	(0.0678)	(0.0300)	(0.0424)	(0.1493)	(0.1371)	(0.0806)	
Food away from home	−1.0915	0.6519	0.6436	0.1409	0.0123	0.0060	577.44
	(0.1487)	(0.0200)	(0.0173)	(0.0504)	(0.1439)	(0.0147)	

[a] Values in parentheses are asymptotic standard errors.

Table 2. Chi-square Test Results, K-P Model versus B-C Model

Curve	National	Rural	Urban	SMSA
Lorenz	182.18	179.92	162.66	179.02
Food at home	60.68	62.38	37.82	13.20
Food away from home	211.40	135.30	147.88	132.22
Critical value		$\chi^2_{.01,3} = 11.34$		

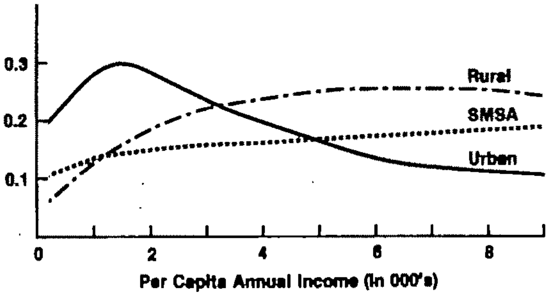

Figure 2. Expenditure elasticities, food at home elasticity

rameters of the B-C curves are presented in table 3. The Gini coefficients estimated from the B-C models are quite close to actual values in all cases. This indicates that the B-C curves gave a very good fit.

In all urbanizations, according to the Gini coefficients, income displayed the largest inequality and food-at-home expenditures showed the least. Food-away-from-home expenditures were almost as unequally distributed as income. Inequality in the distributions of income and food-at-home expenditure appear to be approximately the same across each urbanization. Food-away-from-home expenditures were more equally distributed in the SMSA and rural groups than in the urban section.

Percentage shares of income and expenditures as calculated from the actual data and B-C curves are presented in table 4. The estimated and actual shares are very close in most instances. This provides further evidence to validate the fit of the B-C model. The share of income received by the poorest 5% of the total population was approximately 0.6% and was lower than the percentage share of expenditures for any of the food groups. Conversely, the shares of income and food-away-from-home expenditures for the richest 5% of the population were approximately 19% and 16%, respectively. Further comparisons of percentage shares of income and expenditures received by various population subsets within and across urbanizations are possible with the data in table 4.

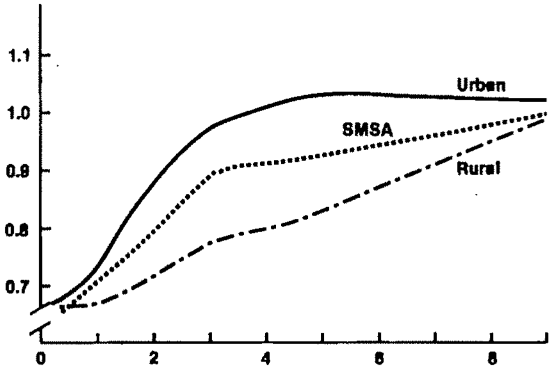

Figure 3. Expenditure elasticities, food away from home elasticity

Conclusions

This paper has shown that elasticity patterns (as income increases) can be diverse and nonmonotonic. The patterns found in this analysis could not be obtained from traditional methods of Engel analysis.

Gini coefficients indicated that income and food-away-from-home expenditures were distributed more unequally across population groups than food-at-home expenditures. Also, food away from home was found to be more unequally distributed within the urban group than within either the rural or SMSA groups. Conversely, the percentage shares of income and food-at-home expenditures by the poorest segments of the population did not vary

Table 3. Gini Coefficients, Actual from Observations and Predicted from B-C Model

	National		Rural		Urban		SMSA	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Income	0.4120	0.4122	0.4171	0.4236	0.4134	0.4141	0.4086	0.4084
Food at home	0.0765	0.0765	0.0817	0.0823	0.0869	0.0869	0.0723	0.0725
Food away from home	0.3654	0.3655	0.3584	0.3585	0.4098	0.4096	0.3460	0.3460

Table 4. Percentage Shares of Income and Expenditures as Calculated from Actual Data and B/C Model

	National		Rural		Urban		SMSA	
	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
Income								
Poorest 5%	0.5777	0.5773	0.5213	0.5216	0.6329	0.6322	0.6143	0.6145
Poorest 10%	1.7212	1.7439	1.6111	1.6148	1.9021	1.9028	1.8089	1.8100
Richest 5%	19.3602	19.3687	19.3503	19.3517	20.0332	20.0475	19.3537	19.3467
Richest 10%	29.9639	30.0011	29.4081	29.4100	30.0192	30.0203	29.9028	29.9181
Food at home								
Poorest 5%	4.0236	3.9425	4.1311	4.1481	3.4440	3.2335	3.9888	3.8792
Poorest 10%	8.0371	7.9749	8.1347	8.4571	7.0104	7.0698	7.9282	8.1191
Richest 5%	6.7541	6.7027	7.1906	6.8130	6.9163	6.5373	6.5825	6.7975
Richest 10%	12.7631	12.7676	12.9872	12.9416	11.8837	12.4169	12.5683	12.8878
Food away from home								
Poorest 5%	1.3315	1.1788	1.5140	1.1335	1.3202	1.2184	1.4348	1.3725
Poorest 10%	2.6376	2.7168	2.9134	2.2855	2.2925	2.2855	2.9007	3.0407
Richest 5%	16.2458	16.2327	20.1745	19.6513	20.2452	21.1928	15.8272	15.6589
Richest 10%	27.2676	27.2958	28.4696	28.6535	33.2497	32.8396	26.1645	26.0372

substantially across urbanizations. The same was true for the richest population subsets.

In summary, several conclusions can be drawn. First, traditional methods for estimating Engel parameters do not allow the flexibility necessary to characterize the varied elasticity patterns that were found in this study. This is important for policy analysis involving the impact of income transfer programs on population subgroups located at the extremes of the income distribution.

Second, procedures outlined in this paper can yield information not directly obtainable from more traditional methods of Engel analysis. For example, Gini coefficients and income and expenditure shares are easy to calculate.

Finally, the B-C model, while more complicated to estimate, is a significant improvement over the K-P function, especially in the tails of the distribution, for estimating Lorenz and concentration curves.

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Causality Tests in Livestock Markets

David A. Bessler and Jon A. Brandt

Bivariate time-series models and related topics of exogeneity and Granger causal orderings have received much attention from economists over the last decade. Examples in the macroeconomic literature include relationships between money and income (Sims 1972, Feige and Pearce), money and interest rates (Pierce), and wages and prices (Geweke 1975). In agricultural markets, research in this area includes the sorting out of leads and lags between farm, wholesale, and retail prices (Heien, Miller), acreage allotments and acreage supply response (Weaver), and alternative price quotes for eggs (Bessler and Schrader).

The methods used in these studies are empirical because they allow the data to specify the dynamic relationship between two variables. Economic theory is used only to suggest the variables to be related. Often theory is ambiguous on the explicit lead-lag relationships between important variables and the variables themselves. In such cases, one can (or must) rely on strictly empirical methods. (Burks discusses the complementary relationship between empirical and theoretical methods in scientific investigations.)

Agriculturalists interested in explaining producer behavior and forecasting livestock price and quantity movements have long grappled with problems of leads and lags. Attempts to explain short-run movements in live cattle and hog inventories or slaughter levels using price variables have at times yielded unsatisfactory results. For example, short-run quantity response to price change was found to be negative for cattle (Nelson and Spreen; Myers, Havlicek, Henderson); however, a positive relation begins to appear with longer lengths of run. The theory of optimal investment under risk explains this type of relationship. That is, treating cattle as both investment goods and as final products will generate the negative short-run response of quantity to price. Such theory, however, will not be explicit about the particular lead-lag relationships to be encountered. Most modern theories of decision making under risk suggest that such lags are dependent upon subjective probabilities of individual economic agents. If one is unwilling to accept the existence of a rational probability (following deFinetti), then he will not be able to specify, a priori, the explicit leads and lags in a particular investment problem. One must look at the data and infer such relationships.

This paper examines the lead-lag relationships between livestock prices and various "causal" variables suggested by theory. It explicitly tests the exogeneity of cattle on feed, cattle slaughter, and income on live cattle prices and the exogeneity of sow farrowings, hog slaughter, and income on live hog prices. Although explicit dynamic multivariate models are not formulated, the paper's results do provide background evidence useful for their ultimate construction (Granger and Newbold 1977, chap. 7).

This paper consists of three parts. First, methods for testing causality between two time-series variables are discussed. Then these methods are applied to movements in livestock prices, livestock quantities, and income. Finally, the implications of the results for modeling and forecasting are discussed.

Inferring Causal Relations

Following Granger, we can say that variable X "causes" variable Y, with respect to a given universe including at least X and Y, if current values of Y can be better predicted by using past values of X than by not doing so—all other information in the universe (including past values of Y) being used in either case (see Geweke 1980, pp. 4–20). Whether or not this concept is consistent with formal definitions of causality offered by philosophers of science is debatable. However, under certain restrictions and simplifying assumptions it does offer an empirically testable definition which has been useful in econometric modeling (Geweke 1980, p. 4).

Various procedures are used in applying the Granger criterion to economic time series. Pierce follows the two-step procedure briefly described here. Because many eocnomic time series are highly autocorrelated and, because inference based on simple regressions or correlations between such series can be misleading, each series is first prefiltered using a separate autoregressive integrated moving average (ARIMA) model. The innovations (residuals) from these ARIMA models are then cross-correlated with long lags. That is, the strength of the relationship between two time series is measured through cross-correlations of residuals

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from prewhitened series. Denoting the estimated cross-correlation of the innovations of X_t and Y_{t+k} as r_k, the procedure requires the calculation of r_k at negative, zero and positive values of k. Negative values are used to study Y_t leading X_t, zero values to study the instantaneous relationship between Y_t and X_t, and positive values to study X_t leading Y_t.

Because individual estimated cross-correlations can be misleading Pierce (p. 15) suggests a portmanteau statistic to test the hypothesis that the cross-correlations are equal to zero at positive or negative lags. The statistic is based on the work of Haugh and is similar to the univariate test given in Box and Pierce. They suggest that the statistic

$$U = N \sum_{k=1}^{m} (r_k)^2$$

be tested against the chi-square distribution at m degrees of freedom (m being an integer large enough to include any suspected relationship, and N, the number of innovations in each series). For relatively large values of U, Pierce suggests rejecting the null hypothesis of independence between the m innovations and, by extension, concluding that X causes Y. An analogous test of U can then be applied over negative values of k to test whether Y causes X.

Sims (1977) has criticized the use of U as a test of one way causality by noting that prefiltering each series with separate ARIMA filters biases the test toward failing to reject the null hypothesis of independence more often than the α-level specified in usual tests suggests. The exact distribution of U under the null hypothesis, when feedback is present, is unknown. The Pierce test is applied in Bessler and Schrader, Miller, and Oliveria and Whittaker.[1]

As an alternative, Geweke (1980, pp. 31–47) suggests a test of the Granger definition which directly utilizes ordinary least squares regression on levels of the series. That is, to test causality running from X to Y, one can use the following specification:

$$(1) \qquad Y_t = a_{10} + \sum_{j=1}^{p} a_{1j} Y_{t-j} + \epsilon_{1t},$$

$$(2) \qquad Y_t = a_{20} + \sum_{j=1}^{p} a_{2j} Y_{t-j} + \sum_{k=1}^{q} b_{2k} X_{t-k} + \epsilon_{2t},$$

where ϵ_{1t} and ϵ_{2t} are white noise residuals, a_{1j} and a_{2j} are parameters relating Y_t and its lagged values, and b_{2k} are parameters relating Y_t and past values of X_t.

The direct Granger test based on (1) and (2) is equivalent to testing the following null hypothesis:

$$b_{21} = b_{22} = \ldots = b_{2q} = 0,$$

which can be carried out with the well-known statistic,

$$F^* = \frac{SSE_1 - SSE_2}{q} \bigg/ \frac{SSE_2}{N - p - q - 1}.$$

Here SSE_1 and SSE_2 refer to the sum of squared errors from ordinary least squares regressions on (1) and (2), respectively, and N is the number of time series observations on Y_t. Under the null hypothesis, F^* is distributed as F with $(q, N - p - q - 1)$ degrees of freedom. For suitably large values of F^*, reject the hypothesis that X does not cause Y.

A test of no instantaneous causality can be based on the residuals from equation (2) and those from

$$(3) \quad Y_t = a_{30} + \sum_{j=1}^{p} a_{3j} Y_{t-j} + \sum_{k=0}^{q} b_{3k} X_{t-k} + \epsilon_{3t},$$

where the symbols a_{3j}, b_{3k}, and ϵ_{3t} are defined as those in equations (1) and (2).

The use of equations (1), (2), and (3) requires that one either chooses values of p and q large enough to remove substantial autocorrelation in the regression residuals or applies generalized least squares. The F-statistic can be seriously overvalued (Granger and Newbold 1974) if substantial autocorrelation is present. One method for selecting values of p and q is to rely on a priori knowledge of possible leads and lags. Where such information is lacking, one can rely on the mechanical methods of Akaike (Bessler and Binkley apply them to univariate model building).

Other causal tests of the Granger definition are available. The test described in Sims (1972)—involving a common prefilter—is valid but not often used. The selection of a proper common prefilter can be troublesome. When the original series are generated by substantially different ARIMA processes, then selection of one prefilter to remove adequately autocorrelation in both series may be impossible. An alternative specification of the Sims test which does not require prefiltering is given by Geweke (1980, pp. 31–47). Finally, Ashley, Granger and Schmalensee extend the Pierce procedure by building bivariate transfer functions and testing causality with out-of-sample prediction. This extension gives tests which have asymptotically valid significance levels.

Application of the Direct Granger Test to Cattle and Hog Markets

The Granger regression test is applied to 1963–79 quarterly price and quantity data from U.S. cattle and hog markets. The bivariate relationships studied in the cattle market are between cattle on feed, cattle slaughter, and consumer disposable income against cattle price. Similarly for hogs, bivariate relationships between sow farrowings, hog slaughter, and consumer disposable income against hog price are analyzed.[2]

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[1] Bessler and Schrader also apply an additional test which has asymptotically valid significance levels. The results of their study indicate that for some series the Pierce test agrees with more proper methods.

Dynamic relationships were specified by the data and not a priori reasoning. However, our prior expectations listed in table 1 reflect both the biological lags inherent in the hog and cattle industries and economic theory.

Sixty ordinary least squares regressions were calculated to test the causal relationships described in table 1. One-way causality tests [following equations (1) and (2)] were performed at both low ($p = q = 4$) and high lags. An upper lag of six was selected for all causality regressions except those involving cattle on feed. An upper lag of nine was used in the cattle on feed regressions. These upper lags were determined by the mechanical procedures of Akaike in Bessler and Binkley. All series except cattle on feed had minimum "final prediction errors" at lags less than or equal to six. All regressions were symmetric in lags ($p = q$). This accounts for forty-eight regressions and the twenty-four F-statistics in table 2. An additional twelve ordinary least squares regressions were estimated [following equation (3)] to test for instantaneous causality. The F-statistics for these tests are given in table 3. The diagnostic Q-statistic of Ljung and Box is given for each test in tables 2 and 3.

From table 2 strong one-way causal relationships run from sow farrowing to hog prices, income to hog prices, hog prices to hog slaughter, cattle price to cattle on feed and income to cattle prices. A weaker relationship runs from hog slaughter to hog price.

Of interest is the relationship between hog prices and sow farrowings. At low lags (4) a very large F-statistic indicates strong one-way causality. However, the Q-statistic is large. The magnitude of the autocorrelation in this regression makes the reliability of the F-statistic questionable. When additional lags are included in the regression (the mechanical method of Akaike suggested an autoregression of lag six), the F-statistic drops drastically. The autocorrelation problems are also reduced.

Another causal relationship of interest runs from cattle price to cattle on feed. Both lag lengths suggest a strong relationship. However the Q-statistic at lag of 4 suggests severe autocorrelation. It is interesting that there is no strong one-way relationship running from cattle on feed to cattle price—suggesting that this variable is not particularly useful as a leading indicator of cattle price.

Turning to instantaneous causality results in table 3, we find strong instantaneous relationships with all variables except between hog price and sow farrowings. While the F-statistic is large for the sow farrowing versus hog price relationship at lag 4, the associated Q-statistic is close to the 5% critical region. Given the results found in table 2, it is probably wise to rely more on the results with 6 lags. Notice that the strongest instantaneous relasionships in both markets are between current price and current slaughter levels. Since it is difficult to store meat much beyond that interval, a single quarter, this result is not surprising.

Some may find the strong instantaneous relationship between livestock prices and income difficult to accept, thinking that income should lead price, as suggested in table 1. This may be what is actually happening, but our three-month interval of observation prevents its detection. Monthly or weekly data might establish such a lead, if it exists.

Conclusions and Implications

This study provides specific evidence on leads and lags of several variables in the hog and cattle markets. This evidence agrees generally with a priori beliefs. The strongest evidence on leads and lags is from sow farrowing to hog prices and from cattle price to cattle on feed. This agrees with the conclusion by Nelson and Spreen (p. 124) that rising prices for as little as one quarter lead to lower marketings (and, by implication, more cattle on feed). In addition, a strong instantaneous relation

Table 1. Prior Expectations on Causality Direction and Time Lags for Six Bivariate Relations

Related Variables and Expected Direction[a]	Time Lags
1. Sow farrowings ↔ hog prices	Sow farrowings should influence hog prices at lags of 2 to 3 quarters. Conversely, hog prices should lead sow farrowings at lags of 4 quarters.
2. Hog slaughter ↔ hog prices	Hog slaughter and hog price should show instantaneous causality.
3. Income → hog prices	Income should lead hog prices at short intervals.
4. Cattle on feed ↔ cattle prices	Cattle on feed and cattle prices should show causal relationships in both directions at both high and low lags.
5. Cattle slaughter ↔ cattle prices	Cattle slaughter and cattle price should show an instantaneous relationship.
6. Income → cattle prices	Income should lead cattle prices at short intervals.

[a] Arrows indicate expected direction of causality between the variables listed in the first column. The one-way direction given for the income relations may, in fact, appear as an instantaneous relation, since our period of observation is one quarter.

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[2] Data used are those described in Bessler and Brandt.

Table 2. One-Way Granger Causality Tests on Hog and Cattle Prices and Related Variables

Hogs				Cattle			
Direction[a]	Lags[b]	*F*-Test[c]	*Q*-Test[d]	Direction[a]	Lags[b]	*F*-Test[c]	*Q*-Test[d]
$HP \rightarrow SF$	4	5.71[e]	61.9[f]	$CP \rightarrow CF$	4	3.25[e]	74.3[f]
$HP \rightarrow SF$	6	2.05	30.7	$CP \rightarrow CF$	9	10.63[e]	24.3
$SF \rightarrow HP$	4	3.48[e]	39.0[f]	$CF \rightarrow CP$	4	2.68[e]	15.0
$SF \rightarrow HP$	6	3.14[e]	17.5	$CF \rightarrow CP$	9	1.37	14.8
$HP \rightarrow I$	4	2.61[e]	12.3	$CP \rightarrow I$	4	1.50	21.5
$HP \rightarrow I$	6	1.37	6.2	$CP \rightarrow I$	6	2.13	13.1
$I \rightarrow HP$	4	5.72[e]	52.6[f]	$I \rightarrow CP$	4	3.29[e]	26.2
$I \rightarrow HP$	6	2.41[e]	29.2	$I \rightarrow CP$	6	3.81[e]	18.8
$HP \rightarrow HS$	4	7.84[e]	38.5[f]	$CP \rightarrow CS$	4	.98	37.3[f]
$HP \rightarrow HS$	6	4.64[e]	36.9[f]	$CP \rightarrow CS$	6	.71	30.1
$HS \rightarrow HP$	4	2.47	33.8	$CS \rightarrow CP$	4	.84	22.0
$HS \rightarrow HP$	6	2.42[e]	23.0	$CS \rightarrow CP$	6	1.22	16.6

[a] Variable abbreviations are *HP* (hog price), *SF* (sow farrowings), *I* (income), *HS* (hog slaughter), *CP* (cattle price), *CF* (cattle on feed), *CS* (cattle slaughter).
[b] Lags refers to the number of autoregressive terms in the vector autoregression.
[c] *F*-test; H_0: Coefficients associated with the causal variable (left side of →) are equal to zero as a group.
[d] Ljung-Box *Q*-test; H_0: residuals of regression have autocorrelations (taken as a whole) not different from zero.
[e] Denotes *F* statistic above critical value at 5% level: $F_{.05}(4,59) \approx 2.53$, $F_{.05}(6,55) \approx 2.27$ and $F_{.05}(9,52) \approx 2.07$.
[f] Denotes *Q* statistic above critical value at 5% level: $\chi^2_{.05}(24) = 36.42$.

between hog and cattle slaughter and hog and cattle prices, respectively, emerged.

Weak causal relationships were found running from hog prices to sow farrowings, from hog prices to income, and from cattle on feed to cattle prices. When strong noninstantaneous relationships are observed, information gains in modeling and forecasting can be made by considering dynamic or feedback regression models.

The results presented are significant because they show that some economic series are related as expected. Heretofore, analyses with macroeconomic data utilizing similar methodology often has failed to establish strong economic relations where theory suggests they should exist. In summarizing a rather frustrating discussion, Pierce (p. 20) concludes: "Our belief is that while most likely there are very strong economic relationships between these variables, they are perhaps inherently not verifiable, empirically, at least using recent period data on the U.S. economy. Our description of the situation may be summed up with the statement, 'The economy is a miserable experimental design.' " While we concur with Pierce's summation, our results offer some evidence that certain sectors can yield "expected" results—although not always. For instance, knowing the size of sow farrowings in quarters $t - 1$ and $t - 2$ can tell us something new about hog prices in quarter t—something not known if we constrained ourselves only to past hog prices. Such information should not be disregarded.

While we find some relationships which are as expected, we find others which are not. Cattle on feed does not seem to lead cattle price. Hog price does not lead sow farrowings (at least not very strongly). Profits rather than hog prices probably

Table 3. Instantaneous Granger Causality Tests on Hog and Cattle Prices and Related Variables

Hogs				Cattle			
Relation[a]	Lags[b]	*F*-Test[c]	*Q*-Test[d]	Relation[a]	Lags[b]	*F*-Test[c]	*Q*-Test[d]
$HP : SF$	4	16.25[e]	33.8	$CP : CF$	4	.50	16.9
$HP : SF$	6	1.62	13.4	$CP : CF$	9	9.61[e]	13.6
$HP : I$	4	10.48[e]	51.8[f]	$CP : I$	4	16.86[e]	24.2
$HP : I$	6	10.26[e]	20.7	$CP : I$	6	14.44[e]	14.9
$HP : HS$	4	81.69[e]	26.1	$CP : CS$	4	51.30[e]	17.6
$HP : HS$	6	35.10[e]	19.4	$CP : CS$	6	38.58[e]	16.1

[a] Variable abbreviations are: *HP* (hog price), *SF* (sow farrowings), *I* (income), *HS* (hog slaughter), *CP* (cattle price), *CF* (cattle on feed), *CS* (cattle slaughter).
[b] Lags refers to the number of autoregressive terms in the vector autoregression.
[c] *F*-test; H_0: Coefficient associated with variable at lag of zero equals zero.
[d] Ljung-Box *Q*-test; H_0: residuals of regression have autocorrelations (taken as a whole) not different from zero.
[e] Denotes *F* statistic above critical value at 5% level: $F_{.05}(1,58) \approx 4.00$, $F_{.05}(1,54) \approx 4.02$.
[f] Denotes *Q* statistic above critical value at 5% level: $\chi^2_{.05}(24) = 36.42$.

would have been a better variable. Both price series show some weak evidence of leading income.

This paper applies causality tests to data from hog and cattle markets. The analysis is performed without use of prefilters and a priori notions on leads and lags. We suggest that further applications of this procedure may yield fruitful results in other markets.

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On Information and Innovation Diffusion: A Bayesian Approach

Gershon Feder and Gerald T. O'Mara

Learning and information accumulation are hypothesized to play a major role in innovation diffusion. For instance, Hiebert argues that the probability distributions of new (and unfamiliar) technological parameters, as perceived by farmers, will shift over time due to learning and experience. Probabilities will be redistributed from lower to higher payoffs. This induces farmers to increase their use of the innovation, which was new seed varieties in the Hiebert model.

The model presented by Kislev and Shchori-Bachrach introduces in the new technology production function an efficiency factor which is positively related to learning. It is approximated by the cumulative (over time) output produced with the innovative technology. As learning increases, the innovation becomes advantageous for more and more producers who then adopt it.

In a similar vein, Feder and O'Mara construct a diffusion process where uncertainty about an innovation (high-yielding varieties [HYV]) depends on cumulative area allocated to HYV. This represents experience. With the accumulation of experience, uncertainty declines, and the innovation is adopted by an increasing proportion of producers.

These models produce sensible (and empirically valid) hypotheses about the dynamics of innovation diffusion. However, the accumulation of information, which is the basic driving element in these models, is not treated explicitly. Thus, the use of cumulative output, or a cumulative input as an index of learning, while plausible, still requires formal justification. One possibility is a Bayesian learning process. Indeed, the work by O'Mara (1971, 1981) and more recently by Lindner, Fischer, and Pardey have utilized Bayes theorem to characterize an individual farmer's adoption behavior.

The purpose of this note is to formulate an aggregative innovation diffusion model based on the assumption that individual farmers revise their beliefs in a Bayesian fashion.

The Model

The traditional technology provides an average profit of R dollars per acre. If the technology is familiar to farmers and has been available for some time, it is reasonable to assume that farmers know the true mean of R.

Assume that the new technology is risky. Profits per acre cultivated with the new technology, say π, are normally distributed with mean μ and variance σ^2, and $\mu > R$. Farmers are assumed to be risk-neutral and believe the mean profit from the new technology is normally distributed with mean m and variance δ^2. Also assume that farmers know the variance of profits, σ^2, with the new technology, and that they modify their beliefs about μ based on new information generated by observed outcomes on areas cultivated with the new technology by adopters in accord with Bayesian procedures. The assumption that farmers' beliefs about μ are normally distributed is not at all restrictive if π is normally distributed. It is easily shown that if farmers' initial beliefs are completely diffuse (i.e., uniformly distributed), and the underlying process is normal, then an application of Bayes Theorem in computing a posterior distribution, using new information, will produce beliefs about μ that are normal.

Since σ^2 is known, the initial beliefs about the variance of μ, (δ_o^2), imply an "equivalent sample size," n_o, associated with prior information, i.e.,

$$\delta_o^2 = \sigma^2/n_o. \tag{1}$$

Using the properties of conjugate prior distributions (Raiffa and Schlaifer, chap. 3) it can be shown that the mean and variance of μ at time t are given respectively by

$$m_t = \frac{\sigma^2 m_{t-1} + \delta^2_{t-1} N A_{t-1} \bar{\pi}_{t-1}}{\sigma^2 + \delta^2_{t-1} N A_{t-1}}, \tag{2}$$

$$\delta^2_t = \frac{\sigma^2 \delta^2_{t-1}}{\sigma^2 + \delta^2_{t-1} N A_{t-1}}, \tag{3}$$

where $\bar{\pi}_{t-1}$ is the sample mean of observations on the new technology generated by the adopters and observed in period $t - 1$, N is the total number of farmers, and A_{t-1} is the proportion of farmers who have adopted the new technology in period $t - 1$.

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For simplicity, assume that all farmers are the same size and that the information content of a farmer's own trial is the same as that of another farmer's. Also, all farms in the population are observable by all farmers. Hence, each farmer acquires the same information about the new technology in each time period, whether or not he is an adopter. These strong assumptions limit the generality of our results. Define $y_t \equiv 1/\delta_t^2$, and substitution in (2) yields

$$y_t = y_{t-1} + \frac{NA_{t-1}}{\sigma^2}, \tag{4}$$

which upon recursive summation becomes

$$y_t = y_o + \frac{N}{\sigma^2}\sum_{i=0}^{t-1} A_i, \tag{5}$$

or equivalently,

$$\delta_t^2 = 1\bigg/\left(\frac{1}{\delta_o^2} + \frac{N}{\sigma^2}\sum_{i=0}^{t-1} A_i\right). \tag{6}$$

Similarly, (1) may be written as

$$\frac{m_t}{\delta_t^2} = \frac{m_{t-1}}{\delta^2_{t-1}} + \frac{N}{\sigma^2}\bar{\pi}_{t-1}A_{t-1}. \tag{7}$$

Defining $z_t \equiv m_t/\delta_t^2$ and substituting in (6), one obtains after recursive summation,

$$z_t = z_o + \frac{N}{\sigma^2}\sum_{i=0}^{t-1}\bar{\pi}_i A_i. \tag{8}$$

Combining (6), (8), and (1) yields

$$m_t = \frac{n_o m_o + N\sum_{i=0}^{t-1}\bar{\pi}_i A_i}{n_o + N\sum_{i=0}^{t-1} A_i}, \tag{9}$$

or in a continuous time formulation,

$$m(t) = \frac{n_o m_o + N\int_0^t \bar{\pi}(\tau)A(\tau)d\tau}{n_o + N\int_0^t A(\tau)d\tau}, \tag{10}$$

Given the assumption of risk neutrality, the condition for adoption becomes

$$E_t(\pi_t) = E_t(\mu) = m(t) \geq R. \tag{11}$$

That is, the time of adoption for a given farmer occurs when the mean of his beliefs about μ, the expected value of profits from the new technology, is at least as great as the return from the old technology. However, $m(t)$ depends not only on initial subjective beliefs (m_o, n_o) but also upon a stochastic component from the realized observations on the process $\pi(t)$, which is distributed $N(\mu, \sigma^2)$ for all t. Hence, the realization $\bar{\pi}(t)$ is also normally distributed with expected value μ for all t. Accordingly, the expected time of adoption for a given farmer is given by the condition,

$$E_t m(t) = \frac{n_o m_o + N\mu\int_0^t A(\tau)d\tau}{n_o + N\int_0^t A(\tau)d\tau} \geq R. \tag{21}$$

This condition may be written, after some manipulation, as

$$m_o \geq R - \frac{N}{n_o}(\mu - R)\int_0^t A(\tau)d\tau = m^*_o(t). \tag{13}$$

Thus, if a farmer is an adopter at time t, his initial beliefs about the expected value of μ must be at least as large as $m^*_o(t)$. Assuming that initial beliefs about the expected value of μ (i.e., m_0) are randomly distributed over all farmers with cumulative density function $F(\cdot)$, the expected aggregate adoption rate at time t is

$$E_t\,A(t) = \text{Prob}[m_o \geq m^*_o(t)] = 1 - F[m^*_o(t)]. \tag{14}$$

For simplicity, denote $P(t) \equiv E_tA(t)$. It can be shown by straightforward derivation (utilizing equations [13] and [14]) that

$$(i)\ \frac{\partial P(t)}{\partial \mu} > 0, \qquad (ii)\ \frac{\partial P(t)}{\partial R} < 0. \tag{15}$$

As one would expect, the expected rate of adoption is higher at any time if the innovation is more profitable, *ceteris paribus,* and lower if the traditional technology is more profitable.

The expected rate of adoption at time zero is given by

$$P(0) = 1 - F(R). \tag{16}$$

It follows, therefore, that the expected rate of adoption at the initial stage does not depend on the innovation's profitability (represented by μ) but rather on the profitability of the old technology and the parameters of the distribution, F. Now, the distribution of initial beliefs is probably strongly affected by sources of information other than observed fields, such as the farmer's education and innate ability, sales promotion, word of mouth reports, extension, etc. The distribution of initial beliefs will also affect the expected rate of adoption later, but then there will be an additional factor—the difference in average profitability between the new and the old technology $(\mu - R)$.

Inspection of equations (14) and (13) verifies that the Bayesian learning process introduces the cumulative adoption rate $\left(\int_0^t A(\tau)d\tau\right)$ as an element in the aggregate expected adoption function. Within the model's context, this is equivalent to the inclusion of cumulative acreage (or output) with the new technology in the adoption function. Previous diffusion models have simply assumed such a relationship. These results serve as a theoretical justification for such an assumption. By differentiating $P(t)$ twice with respect to time, one obtains, after some manipulation,

$$(17)\quad \frac{d^2P(t)}{dt^2} = \ddot{P}(t)$$

$$= \left[\frac{N}{n_o}(\mu - R)\right]^2 \cdot A(t)[(F')^2 - F''A(t)],$$

where $A(t)$ is the actual adoption rate at time t. Clearly,

$$(18)\quad \ddot{P}(t) \gtrless 0 \text{ as } F'' \gtrless (F')^2/A(t).$$

Now, $\ddot{P}$ provides significant information about the curvature of the expected adoption rate function, $P(t)$. If $\ddot{P} > 0$ initially, then $P(t)$ will be strictly convex over that range. Similarly, if $\ddot{P} < 0$ after a certain time $\hat{t}$, then $P(t)$ will be strictly concave after that time. Thus, $P(t)$ will have the sigmoid shape of a typical successful innovation diffusion process if $\ddot{P}$ is first positive and then becomes negative after some time $\hat{t}$ (Griliches). The key to the change in sign of $\ddot{P}$ is the behavior of F'', the latter being the slope of the probability density function, $F'(m_o) \equiv f(m_o)$. Note that if F' has a smooth unimodal shape, as in figure 1, then F'' causes $\ddot{P}$ to be at first positive and then negative. That is, $m^*_o(t)$ will move from the right to the left in figure 1. High values of m_o will be the first to meet the condition $m_o \geq m^*_o(t)$, insuring that $\ddot{P}$ is first positive and then negative. Clearly, the behavior of F'' implies constraints on the distribution of initial beliefs if the adoption curve is to be sigmoid. For example, if F is a uniform distribution, then $F'' = 0$ and the adoption curve is exponential.

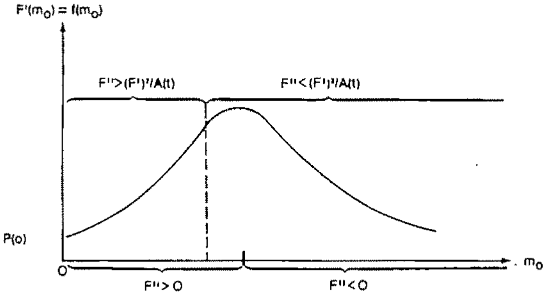

Figure 1. Probability density function of mean profits

Conclusions

This note has shown that, given our assumptions, the Bayesian learning process introduces the cumulative adoption rate as an element in the aggregate expected adoption function. This is equivalent to the inclusion of cumulative acreage (or cumulative output) in the adoption function. Previous models of diffusion have assumed such a relationship. These results serve as a justification for such an assumption. In addition, it was shown that Bayesian learning can generate a characteristic sigmoid-shaped adoption function for a dominant innovation. Although strong assumptions were made, this analysis constitutes a first step toward a more general theory of innovation diffusion.

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Estimation of Substitution Possibilities between Water and Other Production Inputs

Frederick G. Babin, Cleve E. Willis, and P. Geoffrey Allen

The traditional approach to measuring the demand for water by industries relies upon fixed water-use coefficients. Water supply planners base decisions about system expansion partly upon fixed coefficients applied to projected levels of industrial growth. Among the restrictive assumptions implied by this approach is that producers are generally unresponsive to the relative price of water compared with other factors.

Earlier studies focused on industry-by-industry assessments of present and potential water use technologies and the possibilities for substituting other productive inputs for water. Most of these studies are economic engineering in form. Thompson and Young and Russell are analyses of the steam electric-generating industry and the petroleum refining and petrochemical industry, respectively. Because they used linear programming techniques, their results must be interpreted cautiously.

The flexible functional forms which have become popular in recent years allow us to model production activities and to measure both input substitutability and complementarity. The most popular is the transcendental logarithmic (translog) function introduced by Christensen, Jorgensen, and Lau. It has been used in the specification of aggregate production functions in which natural resources are inputs (see Berndt and Wood, Humphrey and Moroney). It is the function we employ here.

Using flexible functional forms to account for water use as a production factor has been limited to Grebenstein and Field. Using translog production and cost functions on a cross-section of pooled U.S. manufacturing data, they estimated partial elasticities of substitution and price elasticities of demand for water, labor, and capital inputs. Water and capital were found to be complements, while water-labor and capital-labor substitutability were discovered. The admitted major weakness of their analysis was the use of a single production function for the entire U.S. manufacturing sector. A second problem was the poor quality water price data used in the study. The first issue is critical because the use of a single production function for all manufacturing implies that all relevant industries will respond to a change in relative input prices in the same way.

This study builds upon the Grebenstein and Field work by examining water use at the standard industrial classification (SIC) two-digit industry level and by employing improved water price information.

Model

The translog form offers several advantages, including the ability to model production relationships with several inputs without imposing stringent conditions on the elasticity of substitution. It has been analyzed in depth in a number of places, including Berndt and Wood, Berndt and Christensen (1973) and Christensen, Jorgensen, and Lau.

The economic theory of duality implies that the production technology may be represented by the cost function (see Shephard). We chose to estimate the cost function rather than the production function because of its relatively straightforward computational requirements and the comparative acceptability of maintained assumptions (see Binswanger for an excellent discussion of these considerations).

The four-input model used in this investigation includes capital services (K), water (W), production employees (P) and nonproduction employees (N) as factors of production. Thus the translog cost function, for a nonhomothetic production structure, can be expressed as

$$(1)\quad \ln C = \ln \beta_0 + \beta_q \ln Q + \Sigma\beta_i \ln P_i + \tfrac{1}{2}\delta_{qq}(\ln Q)^2 + \Sigma\delta_{iq} \ln P_i \ln Q + \tfrac{1}{2}\Sigma\Sigma\delta_{ij} \ln P_i \ln P_j,$$

where $i,j = k,p,n,w$, C is total cost, Q is output, P_i are input prices, and the β_i and δ_{ij} are the parameters to be estimated.

We proceed by assuming that the production technology is linearly homogenous. We may adopt either of two approaches: (*a*) the translog cost function is an exact representation of the production technology, or (*b*) the cost function is an approximation of the true technology. In the former case, parameter restrictions must be imposed to ensure that the translog function is itself linearly homoge-

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nous. Following the latter approach, it should be noted that the approximation to a linearly homogenous production technology can be a cost function which need not be linearly homogenous nor even homothetic. Under this approach, the translog cost function can be interpreted as a Taylor's series expansion in logarithms, and it follows from Young's theorem on the equality of second cross partial derivatives that symmetry exists automatically. In the former case, symmetry is a consequence of the law of production (i.e., cost minimization by producers).

We therefore impose on our model the restrictions of symmetry ($\delta_{ij} = \delta_{ji}, i \neq j, i,j = k,p,n,w$) and linear homogeneity ($\Sigma\beta_i = 1, \beta_q = 1, \delta_{qq} = 0; \Sigma_j\delta_{ij} = 0, \delta_{iq} = 0, i = k,p,n,w$). The function can now be expressed as a translog unit cost function:

$$(2)\quad \ln C/Q = \ln \beta_0 + \Sigma\beta_i \ln P_i + \tfrac{1}{2}\Sigma_i\Sigma_j\delta_{ij} \ln P_i \ln P_j.$$

The estimating equations are share equations in which the dependent variable (S_i) is the ratio of cost of factor i to total cost for each industry and state. Because of the identity $\Sigma_i S_i = 1$, only three of the share equations are independent, and hence we estimate equation (2) with the above restrictions through the three share equations:

$$(3)\quad S_i = \beta_i + \Sigma_j\delta_{ij}\ln(P_j/P_w) + u_i,$$

where $i,j = k,p,n$. The reduced disturbance vector (with S_w removed) is assumed to be independently and identically multivariate normally distributed with a mean vector zero and a constant nonsingular covariance matrix.

Constant output own- and cross-price elasticities of input demand were derived to show the relationships among inputs. These estimates were calculated as

$$(4)\quad \epsilon_{ij} = \frac{\delta^*_{ij} + S^*_i S^*_j}{S^*_i},$$

and

$$(5)\quad \epsilon_{ii} = \frac{\delta^*_{ii} + S^{*2}_i - S^*_i}{S^*_i},$$

where S^*_i and S^*_j are fitted cost shares calculated at the means of the respective independent variables and δ^*_{ii} and δ^*_{ij} are the parameter estimates.

Variable Specification

Because the relationships between cost shares of production factors and their prices form the basis of the estimating equations, data on input quantities and prices were needed to generate the cost share information. Except where noted, data were for two-digit SIC industries by state for 1973. Industry groups analyzed (and their SIC code) were food and kindred products (20); paper and allied products (26); chemicals and allied products (28); stone, clay, and glass products (32); fabricated metal products (34); machinery except electrical (35); and electric and electronic equipment (36). One set of estimations, reported below, pooled these data under the restriction that the parameters were identical across industries. The dependent variables (S_k, S_p, and S_n) were defined as the ratios of the total cost of the particular input in a given industry and state to the total cost for the industry in that state. In turn, the denominator was calculated for each industry and state as the sum of total payroll plus the capital service price multiplied by quantity of capital plus water price multiplied by water utilized.

The price of water in each state was calculated from data published by the American Water Works Association in 1972. Data on quantities and revenues for various water utilities permitted the computation of an average price within each state. These price data are an improvement over the Grebenstein and Field data, which were regional average prices. Like Grebenstein and Field, we were unable to develop a marginal price. Data limitations also forced us to assume that the price levied by public and private water supply agencies was a useful shadow price for water produced directly by firms. If this is untrue, our estimations may be biased.

The price of capital used in the estimating equations was its service price. Christensen and Jorgensen provide the formula for calculating this price series (investment tax credit was assumed to be 0.07 and the rate of replacement 0.13). Lack of published data on capital stock for the year in question forced us to use the perpetual inventory method (Christensen and Jorgensen) to estimate the value of capital stock, beginning with published capital stock data for 1964 and building to 1973 using annual capital investment figures published in the *Annual Survey of Manufacturers.*

Empirical Results

Following Griffin and Gregory, Field and Grebenstein, and others, we have used the iterative Zellner efficient procedure for estimating the parameters of the share equations. The Zellner technique explicitly takes into account nonzero covariances of the errors of one share equation with another by transforming the equations to obtain a zero covariance and minimizing the trace of the transformed residual covariance matrix. Iterating the Zellner efficient procedure until convergence produces results equivalent to maximum likelihood estimates which are invariant to the choice of share equation omitted. These parameter estimates for the seven SIC industry groups plus the pooled data set are shown in table 1. Standard errors for the derived parameters (β_w, δ_{ww}, and δ_{iw}) were calculated as outlined in Kmenta (pp. 443–4) and Klein (p. 258). The parameter estimates show consider-

Table 1. Translog Cost Function Parameter Estimates

Parameter	Pooled	Food and Kindred	Paper and Allied	Chemicals and Allied	Stone, Clay, Glass	Fabricated Metal	Machinery	Electric and Electronic
		Industry						
β_k	0.175 (.005)	0.183 (.004)	0.220 (.010)	0.271 (.012)	0.210 (.009)	0.101 (.003)	0.104 (.004)	0.103 (.003)
β_p	0.517 (.007)	0.484 (.008)	0.528 (.011)	0.356 (.010)	0.545 (.009)	0.623 (.005)	0.543 (.011)	0.558 (.018)
β_n	0.284 (.005)	0.317 (.008)	0.199 (.007)	0.294 (.015)	0.238 (.007)	0.274 (.006)	0.351 (.011)	0.336 (.017)
β_w	0.024 (.006)	0.016 (.007)	0.052 (.009)	0.079 (.012)	0.007 (.008)	0.002 (.005)	0.002 (.010)	0.003 (.010)
δ_{kk}	0.064 (.028)	0.035 (.026)	0.058 (.063)	0.061 (.114)	0.141 (.057)	0.031 (.024)	0.099 (.031)	0.121 (.020)
δ_{kp}	0.023 (.020)	−0.051 (.024)	−0.025 (.045)	0.060 (.070)	−0.037 (.027)	0.003 (.027)	−0.013 (.033)	0.008 (.032)
δ_{kn}	−0.059 (.023)	0.007 (.030)	0.015 (.044)	−0.078 (.114)	−0.097 (.036)	−0.037 (.034)	−0.085 (.045)	−0.132 (.039)
δ_{kw}	−0.028 (.008)	0.009 (.009)	−0.048 (.019)	−0.043 (.025)	−0.007 (.005)	0.003 (.010)	−0.001 (.006)	0.003 (.008)
δ_{pp}	0.085 (.027)	0.013 (.049)	0.113 (.047)	0.037 (.082)	0.150 (.021)	0.109 (.063)	0.341 (.106)	0.304 (.190)
δ_{pn}	−0.123 (.019)	0.064 (.047)	−0.098 (.039)	−0.073 (.090)	−0.114 (.017)	−0.115 (.066)	−0.380 (.103)	−0.312 (.180)
δ_{pw}	0.015 (.008)	−0.026 (.003)	0.010 (.020)	−0.024 (.020)	0.001 (.002)	0.003 (.004)	0.052 (.007)	0.000 (.030)
δ_{nn}	0.181 (.029)	−0.072 (.061)	0.060 (.054)	0.151 (.154)	0.209 (.026)	0.159 (.080)	0.368 (.119)	0.448 (.179)
δ_{nw}	0.001 (.008)	0.001 (.003)	0.023 (.014)	0.000 (.030)	0.002 (.004)	−0.007 (.000)	0.097 (.010)	−0.004 (.009)
δ_{ww}	0.012 (.010)	0.016 (.005)	0.015 (.010)	0.067 (.082)	0.004 (.007)	0.001 (.002)	−0.148 (.004)	0.001 (.012)
Pseudo R^2	0.33	0.21	0.59	0.50	0.93	0.28	0.63	0.65

Note: Asymptotic standard error estimates are in parentheses.

able variation among the individual industry groups and the pooled data set. Also, the explanatory power of the different data subgroups varies widely. The system of cost share equations with pooled data produced a pseudo R^2 of 0.33, while in the stone, clay, and glass products sector (SIC 32), the equations yield a pseudo R^2 of 0.93. This statistic is calculated as $1 - R_1/R_2$, where R_1 is the determinant of the estimated residual covariance matrix of the unconstrained model, and R_2 is that determinant when all of the slope coefficients are constrained to be zero. It collapses to the conventional R^2 when there is a single estimating equation (Berndt, Field and Grebenstein).

Some insight into changes in factor utilization likely to result from relative price changes is provided by the estimated price elasticities of demand, table 2. Estimated own-price elasticities of demand generally carry the expected negative sign. They are positive for SIC groups 35 and 36, implying that the estimated cost functions are not concave in input prices over the data range. However, the standard errors are quite large in these cases, so that the elasticities are not significantly different from zero.

The differences among sectors also are striking. For example, the estimated relationship between capital and water is complementary in three sectors and in the pooled model. However, these two inputs appear as substitutes in sectors 20 (food and kindred products), 34 (fabricated metal products), and 36 (electric and electronic equipment). While the estimated relationship between capital and production workers shows substitutability for all sectors, their magnitudes and standard errors vary considerably. Accordingly, the appropriateness of pooling these sectors was tested. This test for pooling in estimation of share equations with iterative Zellner efficient procedures was suggested by Berndt and Christensen and has been used by Griffin and Gregory and others. It involves calculating the change in the weighted sum of squared residuals from imposing the restrictions divided by the number of restrictions. This quotient is then divided by the ratio of the weighted sum of squared residuals for the unrestricted model to the number of residual degrees of freedom. The resulting test statistic is distributed, asymptotically, as F with the usual degrees of freedom. The calculated F statistic of 19.10 rejects the hypothesis of equal parameters across sectors at the 1% level (the critical value of F, with 54 numerator and 541 denominator degrees of freedom, is approximately 1.5).

Summary and Implications

From the individual sector estimates, it appears that changes in the price of water will have little effect on the usage of other inputs. However, the converse is not true, as indicated by the ϵ_{wi} values. For example, a 1% rise in the price of water would

Table 2. Price Elasticities of Demand for Factors of Production

	Industry Group						
Price Elasticity	Pooled	Food and Kindred	Paper and Allied	Stone, Clay, Glass	Fabricated Metal	Machinery	Electric and Electronic
ϵ_{kk}	−0.46 (.0157)	−0.63 (.142)	−0.52 (.281)	−0.13 (.041)	0.10 (.238)	0.05 (.296)	0.27 (.194)
ϵ_{pp}	−0.32 (.052)	−0.49 (.101)	−2.58 (.089)	−0.18 (.039)	−0.02 (.101)	0.17 (.195)	0.11 (.546)
ϵ_{nn}	−0.08 (.102)	−0.91 (.193)	−0.50 (.273)	0.13 (.112)	−0.15 (.291)	0.40 (.340)	0.66 (1.328)
ϵ_{ww}	−0.56 (.104)	0.14 (.125)	−0.66 (.200)	−0.38 (.080)	−0.41 (.206)	0.14 (.282)	0.54 (.604)
ϵ_{kp}	0.64 (.112)	0.21 (.131)	4.14 (.201)	0.37 (.124)	0.65 (.268)	0.41 (.315)	0.64 (.310)
ϵ_{kn}	−0.05 (.129)	0.35 (.164)	0.26 (.196)	−0.21 (.166)	−0.09 (.337)	−0.46 (.430)	−0.94 (1.278)
ϵ_{kw}	−0.14 (.045)	0.06 (.049)	−0.16 (.085)	−0.03 (.023)	0.03 (.099)	−0.01 (.057)	0.03 (.029)
ϵ_{pk}	0.22 (.039)	0.08 (.049)	1.76 (.085)	0.15 (.050)	0.11 (.043)	0.08 (.061)	0.34 (.014)
ϵ_{pn}	0.45 (.037)	0.45 (.097)	0.01 (.074)	0.02 (.031)	0.09 (.106)	−0.35 (.190)	−0.22 (.560)
ϵ_{pw}	0.05 (.016)	−0.04 (.006)	0.07 (.038)	0.01 (.004)	0.01 (.006)	0.10 (.013)	0.00 (.000)
ϵ_{nk}	−0.03 (.081)	0.20 (.095)	0.30 (.223)	−0.20 (.155)	−0.03 (.124)	−0.14 (.129)	−0.29 (.391)
ϵ_{np}	0.81 (.067)	0.69 (.148)	0.03 (.197)	0.05 (.073)	0.21 (.240)	−0.54 (.294)	−0.37 (.925)
ϵ_{nw}	0.03 (.028)	0.02 (.009)	0.17 (.071)	0.01 (.017)	−0.02 (.000)	0.07 (.029)	−0.01 (.012)
ϵ_{wk}	−1.11 (.356)	0.82 (.635)	−0.71 (.373)	−0.92 (.785)	1.90 (6.012)	−0.26 (3.015)	1.48 (1.379)
ϵ_{wp}	1.18 (.356)	−1.35 (.212)	0.73 (.393)	0.76 (.314)	2.43 (2.405)	18.02 (3.518)	0.56 (.000)
ϵ_{wn}	0.33 (.356)	0.39 (.212)	0.64 (.275)	0.55 (.628)	−3.93 (.000)	8.90 (5.025)	−1.50 (1.839)

Note: Asymptotic standard error estimates are in parentheses. These were calculated as $\mathrm{var}(\epsilon^*_{ij}) = \mathrm{var}(\delta^*_{ij})/S^{*2}_i$.

result in a 0.16% drop in the use of capital for the paper and pulp industry (SIC 26). Such a small response makes sense because of the relatively small cost share of the water input. On the other hand, a 1% rise in the cost of capital services for the same industry would lead to a 0.71% reduction in water use.

An important result is that one cannot assume that the industries studied here can be pooled on the basis of identical parameters. Our estimates found capital and production labor to be substitutes in all industry groups analyzed. However, all other pairs of inputs were found to be substitutes for some industries and complements for others. Thus, water planners are likely to find that elasticities based on pooled data are unreliable indicators of price responsiveness for their specific industrial customers.

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Duality, the Output Effect, and Applied Comparative Statics

Robert G. Chambers

The "dual" approach to applied production analysis (e.g., Binswanger, Kako, and Lutton) often concentrates on substitution relationships via estimated cost and factor demand functions. This is because the cost function presents as accurate a description of technology as the production function.

Except for Kako, agricultural production studies using cost functions have analyzed technology via Allen elasticities, technological change parameters, and homotheticity tests. Kako used a transcendental logarithmic (translog) cost function to decompose empirically changes in derived factor demand into three separate components—output level, factor substitution effects, and technical change. Kako's work allows further investigation of technical change on derived factor demands. However, Kako's "output effect" is different from the traditional concept, the production analog of the "income effect" in consumer theory. This note outlines a theoretical and econometric approach for measuring the output effect.

The output effect is important because it presents a more complete picture of factor employment adjustments than do demand elasticities generated from cost functions. Elasticities generated from cost functions restrict the producer to a given level of output. Producers, however, may also adjust output as factor prices change. The output effect captures this adjustment.

This paper demonstrates a method for deriving the output effect from the cost function. First, the general assumptions and the model are outlined. Then the cost function is related to the indirect production function, and the output effect obtained. Results are presented for the special case of a homothetic production function. The paper concludes with an empirical application to the U.S. meat products industry.

Cost and Indirect Production Functions

Assume a production function,

$$y = f(\mathbf{x}), \tag{1}$$

which is concave, strictly increasing, and twice continuously differentiable in all inputs $(x_i \epsilon \mathbf{x})$. The cost function $C(\mathbf{w},y)$ is defined by

$$C(\mathbf{w},y) = \underset{\mathbf{x}}{\text{Min}}\, [\mathbf{w} \cdot \mathbf{x} : y = f(\mathbf{x})], \tag{2}$$

where $\mathbf{w}$ represents a vector of factor prices. $C(\mathbf{w},y)$ satisfies (*a*) nondecreasing in $\mathbf{w}$ and y; (*b*) positively linearly homogenous in $\mathbf{w}$; and (*c*) concave in $\mathbf{w}$. It is assumed that $C(\mathbf{w},y)$ is twice continuously differentiable in all its arguments.

Producing a given output at minimum cost is only one of many possible behavioral assumptions. Another is output maximization subject to a cost constraint (Ferguson). Ultimately, all agricultural producers face an upper limit on the amount they can spend on factors of production. In many instances, this limit provides an effective constraint preventing unlimited profit maximization. In these cases, it may be appropriate to assume that firms maximize profits by maximizing the output attainable for this given cost.

The indirect production function is defined by

$$V(\mathbf{w},c^*) = \underset{\mathbf{x}}{\text{Max}}\, [f(\mathbf{x}) : \mathbf{w} \cdot \mathbf{x} = c^*]. \tag{3}$$

$V(\mathbf{w},c^*)$ is the maximum output producible at predetermined cost level c^*. This function possesses the following properties: (*a*) quasi-convex in $\mathbf{w}$; (*b*) nonincreasing in $\mathbf{w}$ and nondecreasing in c^*; and (*c*) homogenous of degree zero in $\mathbf{w}$ and c^*. It is assumed that $V(\mathbf{w},c^*)$ is twice continuously differentiable. The indirect production function is the production analog of the indirect utility function.

The optimization problems in (2) and (3) are similar. The principle that determines optimal input usage, equating the marginal rate of technical substitution to the ratio of factor prices, is the same for both problems. In fact, if $\mathbf{x}^*$ is the solution to (2), then $\mathbf{x}^*$ also solves (3) if the cost constraint is $c^* = \mathbf{w} \cdot \mathbf{x}^*$. Thus, if $C(\mathbf{w},y)$ is strictly increasing in y the indirect production function can be obtained by solving

$$C(\mathbf{w},y) = c^* \tag{4}$$

for y in terms of $\mathbf{w}$ and c^*. Parameter estimates of the indirect production function for observed costs are obtained by inverting the estimated cost function. The invertibility of the expenditure function to obtain the indirect utility function is demonstrated in Varian. Extension to the cost and indirect production functions is obvious. However, y is treated as predetermined in (2). In (3) the output level is

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determined by the solution of the optimization problem. Strictly speaking, y should be treated as jointly dependent in the estimation of the cost function before it is inverted to obtain the indirect production function. In the case below, where factor demands are estimated in the form $(\mathbf{x}_i/y^2)$, the stochastic specification incorporates this simultaneity.

Applied Comparative Statics

The partial derivative of the cost function with respect to $\mathbf{w}_i$ is the ith constant output demand $\mathbf{x}_i(\mathbf{w},y)$ (Kako). Furthermore, since $V(\mathbf{w},c^*)$ has the same properties as the indirect utility function, Roy's identity shows that the constant cost input demand (the optimal $\mathbf{x}_i$ for [3]) is

$$(5)\qquad M_i(\mathbf{w},c^*) = -\frac{\partial V(\mathbf{w},c^*)/\partial \mathbf{w}_i}{\partial V(\mathbf{w},c^*)/\partial c^*},$$

where $i = 1, 2, \ldots, n$.

The basic difference between $M_i(\mathbf{w},c^*)$ and $\mathbf{x}_i(\mathbf{w},y)$ can be seen by analogy with consumer theory. The constant cost demand function, $M_i(\mathbf{w},c^*)$, corresponds to the Marshallian demand function, while $\mathbf{x}_i(\mathbf{w},y)$ corresponds to the Hicksian compensated demand. In further analogy with consumer theory, it is possible to decompose the price adjustment of $M_i(\mathbf{w},c^*)$ into two components: the adjustment of the compensated demand function which measures substitution effects and an adjustment in the level of output—the output effect. These two components can be represented by the Slutsky equation which, because of this symmetry between the producer and consumer problems, can be represented conveniently in dual form following Cook, as (Slutsky equation)

$$(6)\qquad \frac{\partial M_i(\mathbf{w},c^*)}{\partial \mathbf{w}_j} = \frac{\partial \mathbf{x}_i[\mathbf{w},V(\mathbf{w},c^*)]}{\partial \mathbf{w}_j} - \frac{\partial M_i(\mathbf{w},c^*)}{\partial c^*} M_j.$$

Obtaining an estimate of the output effect involves calculating the appropriate second partial derivative of the estimated cost function $\left(\frac{\partial^2 c}{\partial \mathbf{w}_i \partial \mathbf{w}_j} = \frac{\partial \mathbf{x}_i}{\partial \mathbf{w}_j}\right)$, evaluating it at $y = V(\mathbf{w},c^*)$, and subtracting it from the estimate of (6) derived by inverting the cost function. One also could calculate the output effect directly from the derived estimate of the indirect production function using Roy's identity (5). Inversion of $C(\mathbf{w},y)$ may be difficult. However, one can implicitly differentiate (4), use Roy's identity and the Slutsky equation to obtain the output effect. An example of this approach follows for the case of a homothetic technology.

Output Effects for a Homothetic Technology

Homothetic production functions are important in applied production analysis. Special cases of homothetic production functions include the Cobb-Douglas and constant elasticity of substitution production functions. A production function is homothetic if it can be written as

$$(7)\qquad h(y) = f^*(\mathbf{x}),$$

where $f^*(\mathbf{x})$ is a linearly homogenous and otherwise standard production function and $h(y)$ strictly increases from zero to infinity (Hanoch). The associated cost function is

$$(8)\qquad C(\mathbf{w},y) = h(y)c(\mathbf{w}),$$

where $c(\mathbf{w})$ is the cost of producing output level $y = h^{-1}(1)$. Hence, one form of the indirect production function is

$$(9)\qquad h(y) = \frac{c^*}{c(\mathbf{w})}.$$

Implicit differentiation yields

$$(10)\qquad M_i(\mathbf{w},c^*) = \frac{c^*\left(\dfrac{\partial c(\mathbf{w})}{\partial \mathbf{w}_i}\right)}{c(\mathbf{w})}.$$

Thus, constant cost input demand (M_i) is proportional, at given prices, to $\mathbf{x}_i(\mathbf{w},y)$ for output level $y = h^{-1}(1)$. The factor of proportionality is $\frac{c^*}{c(\mathbf{w})}$. Differentiating (10) with respect to $\mathbf{w}_j$ yields the left-hand side of the Slutsky equation:

$$(11)\qquad \frac{\partial M_i(\mathbf{w},c^*)}{\partial w_j} = \frac{c^*\left[\dfrac{\partial^2 c(\mathbf{w})}{\partial \mathbf{w}_i \partial \mathbf{w}_j} c(\mathbf{w}) - \dfrac{\partial c(\mathbf{w})}{\partial \mathbf{w}_i} \cdot \dfrac{\partial c(\mathbf{w})}{\partial \mathbf{w}_j}\right]}{c(\mathbf{w})^2}$$

Using Shephard's lemma with $c(\mathbf{w})$ obtains

$$\mathbf{x}_i^0 = \frac{\partial c(\mathbf{w})}{\partial \mathbf{w}_i},$$

where $\mathbf{x}_i^0$ is the cost-minimizing input used to produce $y = h^{-1}(1)$. Equation (11) can be decomposed in the same manner as (6) and expressed as

$$(12)\qquad \frac{\partial M_i(\mathbf{w},c^*)}{\partial \mathbf{w}_j} = \frac{\partial \mathbf{x}_i^0}{\partial \mathbf{w}_j} \frac{c^*}{c(\mathbf{w})} - \frac{\mathbf{x}_i^0 \mathbf{x}_j^0 c^*}{c(\mathbf{w})^2}.$$

The last term on the right-hand side of (12) is the output effect (θ_{ij}) and may also be obtained by differentiation of (10) with respect to c^* and use of (6). For homothetic production, θ_{ij} is symmetric $(\theta_{ij} = \theta_{ji})$ and negative. Symmetry of θ_{ij} implies symmetry of the overall uncompensated effect since the substitution effect is always symmetric. Negativity implies all own-price effects are negative since by concavity of $c(\mathbf{w})$, $\partial \mathbf{x}_i^0/\partial \mathbf{w}_i \leq 0$.

Multiplying equation (12) by (w_j/M_i) and substitution obtains

$$(13)\quad \frac{\partial \ln M_i(\mathbf{w},c^*)}{\partial \ln \mathbf{w}_j} = \frac{\partial \ln \mathbf{x}_i^0}{\partial \ln \mathbf{w}_j} - \frac{\mathbf{x}_j^0\mathbf{w}_j}{c(\mathbf{w})} = \frac{\partial \ln \mathbf{x}_i^0}{\partial \ln \mathbf{w}_j} - S_j.$$

When expressed in elasticity form, the output effect for a homothetic technology is the negative optimal cost share of the jth factor (S_j). This result can also be obtained from Mundlak's representation of the production Slutsky equation and the recognition that homothetic production implies that the elasticity of M_i with respect to c^* is one. Expression (13) also implies that for a homothetic technology the output effect in elasticity form associated with a change in $\mathbf{w}_j$ is the same for all M_i.

Homotheticity generates an interesting relationship between the Allen elasticity of substitution (σ_{ij}) and the output effect. Following Uzawa,

$$(14)\quad \sigma_{ij} = \frac{(\partial \mathbf{x}_i^0/\partial \mathbf{w}_j)\, c\,(\mathbf{w})}{\mathbf{x}_i^0\mathbf{x}_j^0} = \frac{E_{ij}}{S_j},$$

where $E_{ij} = \left(\frac{\partial \mathbf{x}_i^0}{\partial \mathbf{w}_j}\right)\left(\frac{\mathbf{w}_j}{\mathbf{x}_i^0}\right)$,

which with (12) implies

$$(15)\quad \theta_{ij} = -\frac{(\partial \mathbf{x}_i^0/\partial \mathbf{w}_j)c(\mathbf{w})}{c(\mathbf{w})\sigma_{ij}} = -\frac{(\partial \mathbf{x}_i^0/\partial \mathbf{w}_j)\, M_i}{\mathbf{x}_i^0\sigma_{ij}} = -\frac{E_{ij}\, M_i}{\mathbf{w}_j\sigma_{ij}},$$

where the second equality follows from (10). The output effect is proportional (for given $\mathbf{w}$) to the comparative static effect of a change in $\mathbf{x}_i^0$ for a change in $\mathbf{w}_j$. These results imply

$$(16)\quad \frac{\partial M_i}{\partial \mathbf{w}_j} = \frac{\partial \mathbf{x}_i^0}{\partial \mathbf{w}_j}\left\{h[V(\mathbf{w},c^*)] - \frac{c^*}{c(\mathbf{w})\sigma_{ij}}\right\}.$$

Equation (16) illustrates an interesting characteristic of homothetic production functions. If σ_{ij} equals one, there is no adjustment in the use of input i as the price of j changes and costs are held constant. The substitution effect is exactly balanced by the output effect. For example, the Cobb-Douglas production function is characterized by $\sigma_{ij} = 1$ across all input pairs. Thus, (16) implies that for a Cobb-Douglas production function all constant-cost, cross-price elasticities are zero.

In general, $c(\mathbf{w})$ may not be readily available or analytically tractable. However, there is one important subclass of homothetic functions for which it is—linearly homogenous functions. For a linearly homogenous production function $h^{-1}(1) = 1$, and $c(\mathbf{w})$ is the cost associated with a unit output.

An Application to the U.S. Meat Products Industry

Consider the following generalized Leontief specification of the cost function for the meat products (SIC201) industry:[1]

$$C(\mathbf{w},y) = y^2[\Sigma_j\Sigma_i\beta_{ij}\mathbf{w}_i^{\frac{1}{2}}\mathbf{w}_j^{\frac{1}{2}}],$$

where $i,j = K,L,E,M,S$; K is capital equipment; L is labor; E is energy; M is intermediate materials; S is capital structures; and it is assumed that $\beta_{ij} = \beta_{ji}$. This specification is linearly homogenous in $\mathbf{w}$. A sufficient condition for it to be globally concave and nondecreasing in $\mathbf{w}$ and y is that all of the parameters be nonnegative (Diewert). This condition is apparently overly restrictive since nonnegative β_{ij}'s $(i \neq j)$ rule out the possibility of complementary behavior among inputs. However, one can always impose global concavity using the method developed by Lau. Because the basic aim of this section is to illustrate a method and not to analyze fully the meat products industry, this restriction was not imposed.[2]

To permit estimation, it is assumed that the observed ratios $\left(\frac{\mathbf{x}_i}{y^2}\right)$ are distributed stochastically about the optimal ratios. Shephard's lemma, therefore, implies

$$(17)\quad \left(\frac{\mathbf{x}_i}{y^2}\right) = \sum_{j=1}^{n} \beta_{ij}\left(\frac{\mathbf{w}_j}{w_i}\right)^{\frac{1}{2}} + \epsilon_i,$$

where $i,j = K,L,E,M,S$; and ϵ_i is assumed to be intertemporally independent and identically normally distributed with mean zero and unknown homoscedastic variance. Since $C(\mathbf{w},y)$ is linearly homogeneous in $\mathbf{w}$, it is sufficient to estimate the demand equations in (17). These equations were estimated by maximum likelihood methods using annual data for the period 1954–76.[3] The estimated demand equations are as follows:

$$\frac{\mathbf{x}_K}{y^2} = \underset{(.02325)}{.13019} + \underset{(.01423)}{.01445}\left(\frac{\mathbf{w}_L}{\mathbf{w}_K}\right)^{\frac{1}{2}} + \underset{(.0082)}{.00410}\left(\frac{\mathbf{w}_E}{\mathbf{w}_K}\right)^{\frac{1}{2}} - \underset{(.0291)}{.03599}\left(\frac{\mathbf{w}_M}{\mathbf{w}_K}\right)^{\frac{1}{2}} + \underset{(.0224)}{.03446}\left(\frac{\mathbf{w}_S}{\mathbf{w}_K}\right)^{\frac{1}{2}},$$

$$\frac{\mathbf{x}_L}{y^2} = \underset{(.0386)}{-.08571} + \underset{(.01423)}{.01445}\left(\frac{\mathbf{w}_K}{\mathbf{w}_L}\right)^{\frac{1}{2}} + \underset{(.0078)}{.00037}\left(\frac{\mathbf{w}_E}{\mathbf{w}_L}\right)^{\frac{1}{2}} + \underset{(.0821)}{.31510}\left(\frac{\mathbf{w}_M}{\mathbf{w}_L}\right)^{\frac{1}{2}} + \underset{(.0129)}{.01368}\left(\frac{\mathbf{w}_S}{\mathbf{w}_L}\right)^{\frac{1}{2}}$$

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[1] The meat products industry includes firms that are engaged in meat packing, manufacture of sausage and prepared meat products, poultry dressing, and poultry and egg processing.

[2] The restriction of global concavity has been imposed in the framework of a more general study of the meat products industry using a generalization of the cost function specified in this paper (see Ball and Chambers).

[3] The data are time series data for the period 1954–76 and are derived from data used in Lutton's study of the food-processing industry. Lutton's data consist of observations on *K, L, M, S,* and four separate energy inputs and input prices. The original energy inputs are aggregated into a single input for this study. All data are available upon request.

$$\frac{x_E}{y^2} = \underset{(.0093)}{.00689} + \underset{(.0082)}{.00410}\left(\frac{w_K}{w_E}\right)^{\frac{1}{2}} + \underset{(.0078)}{.0037}\left(\frac{w_L}{w_E}\right)^{\frac{1}{2}} + \underset{(.0218)}{.00649}\left(\frac{w_M}{w_E}\right)^{\frac{1}{2}} + \underset{(.0095)}{.00095}\left(\frac{w_S}{w_E}\right)^{\frac{1}{2}},$$

$$\frac{x_M}{y^2} = \underset{(.2275)}{3.1091} - \underset{(.0291)}{.03599}\left(\frac{w_K}{w_M}\right)^{\frac{1}{2}} + \underset{(.0821)}{.31510}\left(\frac{w_L}{w_M}\right)^{\frac{1}{2}} + \underset{(.0218)}{.00649}\left(\frac{w_E}{w_M}\right)^{\frac{1}{2}} + \underset{(.0279)}{.03106}\left(\frac{w_S}{w_M}\right)^{\frac{1}{2}}, \text{ and}$$

$$\frac{x_S}{y^2} = -\underset{(.0465)}{.07036} + \underset{(.0224)}{.03446}\left(\frac{w_K}{w_S}\right)^{\frac{1}{2}} + \underset{(.0219)}{.01368}\left(\frac{w_L}{w_S}\right)^{\frac{1}{2}} + \underset{(.0095)}{.00095}\left(\frac{w_E}{w_S}\right)^{\frac{1}{2}} + \underset{(.0279)}{.03106}\left(\frac{w_M}{w_S}\right)^{\frac{1}{2}}.$$

Numbers in parentheses are asymptotic standard errors. For the estimated model, only three parameters (β_{KM}, β_{LL} and β_{SS}) are negative. Thus, if there is a departure from concavity for the model, it probably is slight. The estimated coefficients imply only one negative Allen elasticity of substitution. Therefore, only capital equipment and intermediate materials can be classified as complements. All others are substitutes.

Since this cost function is homothetic, an accurate elasticity measure of the output effect is provided by the respective S_i. Estimated cost shares for the last year of the sample (1976) are reported in table 1. These results indicate that the largest relative output adjustments occur in response to changes in the price of intermediate materials. The smallest output adjustments are made in response to changes in the price of energy.

Both substitution and uncompensated elasticities are reported in table 1. When considering the pure substitution effect, only capital and intermediate materials behave in a complementary manner. If the level of output is allowed to adjust as factor prices change, however, materials have a complementary relationship with all inputs except labor, and labor and energy behave as gross complements. The differences between the compensated and uncompensated elasticities highlight the importance of the output effect in applied comparative static analysis.

Concluding Remarks

This paper demonstrates how to use estimates of dual cost functions to generate estimates of some common economic concepts. Specifically, transforming a cost function to the indirect production function permits estimation of the output effect. These expressions are particularly simple when the underlying technology is homothetic.

However, if the indirect production function is estimated instead of the cost function, it is a simple matter to revise the outlined procedure to obtain estimates of the substitution effect and the associated Allen elasticities of substitution. Just invert the estimated indirect production function at the observed level of output and solve for costs.

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Table 1. Estimated Cost Shares, Compensated and Uncompensated Demand Elasticities, 1976

	Capital (K)	Labor (L)	Energy (E)	Materials (M)	Structures (S)
Cost Share	.01275	.07499	.00745	.89995	.00485
		Output Compensated Demand (Substitution) Elasticities			
Capital (K)	−.07134	.16619	.03539	−.20014	.06990
Labor (L)	.02825	−1.08532	.00019	1.0404	.01647
Energy (E)	.06055	.00192	−.23307	.16192	.00867
Materials (M)	−.00283	.08669	.001341	−.08671	.00150
Structures (S)	.18358	.25449	.01331	.27949	−.73088
		Uncompensated Demand Elasticities			
Capital (K)	−.08409	.09119	.02794	−1.10009	.06504
Labor (L)	.01550	−1.16031	−.00725	.14045	.01162
Energy (E)	.04780	−.07307	−.24052	−.73803	.00382
Materials (M)	−.01558	.01170	−.00611	−.98666	−.00335
Structures (S)	.17084	.17949	.00586	−.62045	−.73574

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Optimum Effort and Rent Distribution in the Gulf of Mexico Shrimp Fishery: Comment

Lee G. Anderson

In a 1976 *Journal* paper Griffin, Lacewell, and Nichols (GLN) present a discussion of optimal utilization of fisheries which directly considers the share system of remuneration and the possibility that some costs are related to the catch size. They present two main conclusions. First, adherence to the traditional fisheries model will lead to incorrect policy recommendations if its assumptions do not hold. Second, with a fixed-share system, if the fishery is operating at less than the open access equilibrium level of effort, the earned rents will be distributed between vessel owners and crew members. In the traditional model, where labor is assumed to receive an opportunity cost wage rate, any accrued rents will go only to vessel owners. The conclusion that rents can be earned by crew members has important distribution and efficiency implications and is a contribution to literature on fisheries economics. However, the article contains the three errors which weaken its impact and could lead to an improper interpretation of these implications.

(*a*) The equation derived for optimal fishery utilization erroneously indicates that the optimal level of effort depends upon the share rate chosen.

(*b*) In the empirical estimates section, they correct for the above error but introduce another by allowing a transfer payment to be included as an opportunity cost measure.

(*c*) They incorrectly conclude that, to achieve an optimal level of effort using a tax system, both vessel owners and crew members have to be taxed. In addition, there is a general misconception in the paper captured in the following quote from the abstract. "When crews receive a fixed share of gross returns, labor costs are proportional to catch . . . ." This is only true for pecuniary or financial costs. In their model the opportunity cost of labor is not affected by the way revenues and/or cash costs are shared. The first two of their errors are related to this confusion between financial and opportunity cost.

What GLN call the traditional model can be summarized by the following total fishery profit function.

$$(1) \qquad \pi = Pf(E) - rE,$$

where P is fixed price of fish; $f(E)$, sustainable yield of the fishery; E, amount of effort applied to the stock; and r, opportunity cost of effort. The rent to the fishery in the traditional model is therefore maximized when

$$(2) \qquad f'(E) = \frac{r}{P},$$

where $f'(E)$ is the first derivative of $f(E)$.

Now consider the GLN model in which r_1 is the unit opportunity cost proportional to output incurred by vessel owners; r_2, the opportunity cost of labor associated with each unit of effort; r_3, the unit opportunity cost proportional to "their share of catch" incurred by the crew; r_4, the opportunity cost of nonlabor inputs associated with each unit of effort; and s, fixed percentage of total revenue going to crew. The total profit function for all of the vessels in the fishery can be expressed as

$$(3) \qquad \pi_v = Pf(E) - sPf(E) - r_1 f(E) - r_4 E.$$

That is, profit or rent to vessels is the difference between total revenue and the sum of that part of total revenue distributed to the crew plus costs paid by vessel owners.

Following GLN, the total rent earned by all crew members is

$$(4) \qquad \pi_c = sPf(E) - sr_3 f(E) - r_2 E.$$

That is, the rent earned by crew members is the difference between the net amount they receive from fishing (their share of revenues minus their share of costs) minus the opportunity wage they could earn elsewhere. This is the essence of GLN's model.

The total rent produced by the fishery is the difference between the value of the output and the opportunity cost of producing it. This can be derived by adding equations (3) and (4). The result is

$$(5) \quad \pi = Pf(E) - (r_2 + r_4)E - r_3 sf(E) - r_1 f(E).$$

According to the GLN model, then, the economically efficient level of effort can be obtained from the following equation:

$$(6) \qquad f'(E) = \frac{r_2 + r_4}{P - (r_3 s + r_1)}.$$

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Unaccountably GLN express the term in parentheses in the denominator of their equation (8) as $(r_3s - r_1)$.

In any event, the nature of the first error can now be seen. According to this equation (6), the optimal level of E depends upon the fixed share rate. They get this result from their peculiar set of assumptions concerning the cost associated with output. Looking at equation (5) one might ask why the entire catch results in unit costs of r_1 but only a certain percentage of it (the share rate) results in an additional unit cost of r_3. What is so special about "their share of catch" to require additional opportunity costs? To put it another way, how can the opportunity cost of handling catch possibly be related to the share rate?

It is unfortunate that the theoretical section of the GLN paper contains such a significant error from a policy point of view, especially since they make an empirical correction so that their calculations do not suffer from it.

On page 649, when deriving the opportunity cost parts of r_1 and r_3, GLN introduce the parameter k, the average packing charges for landings. They state that

$$r_1 = (1 - s)k,$$

$$r_3 = k.$$

Recall that in the GLN definitions of r_1 and r_3, r_3 was defined specifically to cover the crew's share of the catch, but r_1 was not limited to the vessel's share. However, by defining r_1 as $(1 - s)k$, it is clear that GLN meant that owners pay only those costs proportional to output which are not paid by the crew.

This idea should have been built directly into the theoretical model. An easy way to do it would be to introduce the concept of the landings charges directly and then state that they are shared by boat owner and crew in the same proportion as are revenues. In this case, the term $r_1f(E)$ in the boat rent equation, (3), would be replaced by $(1 - s)kf(E)$, and the term $sr_3f(E)$ in the crew rent equation, (4), would be replaced by $skf(E)$. The sum of the two rents then becomes

$$\pi = Pf(E) - (r_2 + r_4)\,E - kf(E). \tag{7}$$

The correct equation for the optimal level of effort, then, is

$$f'(E) = \frac{r_2 + r_4}{P - k}. \tag{8}$$

Here it can be seen that s, the share rate, does not enter and the optimal level of E is independent of s.

By using the above expressions for r_1 and r_3, the denominator term in the parentheses in equation (6) becomes

$$r_1 + r_3s = (1 - s)k + sk = k.$$

Therefore, the formulation provided in the empirical section translates equation (6) into the proper optimizing equation as expressed in (8). This means that, at least with respect to landings charges, the calculations they make are correct. See below, however.

From equations (2) and (8) it can be seen that the fundamental difference between the optimal point in the traditional model and the corrected GLN model is quite small. The numerator in both is the marginal opportunity cost of effort. Likewise, the denominator in both is the net value of a unit of output. There is a difference in the two models due to the introduction of costs proportional to catch in the GLN model. However, it is landing charges and not the share system that provides the difference between the two models in optimal output determination.

GLN are correct when they state that use of the traditional model, when it does not apply, will lead to incorrect policy recommendations. If costs which are proportional to output are somehow lumped into the numerator of equation (2) instead of being treated properly in the denominator, both numerator and denominator will be larger than they should be. Then it will be impossible to determine if the E so derived will be less than, equal to, or greater than the true, optimal E.

The second error is that GLN miscalculated the optimal level of E because they included a transfer payment in their cost measure. In measuring r_1 (page 649), they include a term tsP, where t is a percentage payroll tax. While this tax is a financial cost to vessel owners, it clearly is not an opportunity cost of handling fish. It is just a transfer payment to government. Since it is not an opportunity cost it has no relevance in the determination of the optimal level of effort. Since the r_1 they actually use in estimating the optimal level of E is

$$r'_1 = (1 - s)k + tsP,$$

then the term in the parentheses in equation (6) is

$$r'_1 + r_3s = k + tsP.$$

Therefore, their calculations do not actually allow equation (6) to reduce to the correct optimizing equation of equation (8). Specifically, the right-hand side of (6) is smaller than it should be. Since $f'(E)$ is assumed to be a diminishing function of E, GLN have underestimated the optimal level of E. Also since they estimate r from the values of r_1, r_2, r_3, and r_4, their estimate of the optimal E, using the traditional model, is also incorrect.

The third error is their statement that in order for a tax program to achieve the optimal effort level in a fishery with a fixed share rate, it must tax the rent from both crew members and vessel owners. To see that this is not correct, note that if all boat owners can get crews at the existing share rate, the open-access equilibrium for the fishery occurs where boats profits are zero. Modify equation (3) by replacing the term $r_1f(E)$ by $(1 - s)kf(E)$. Then this open-access equilibrium condition can be expressed as

$$(9) \qquad (1 - s)\,(P - k)\,\frac{f}{E} - r_4 = 0.$$

From equation (8) the optimal condition can be expressed as

$$(10) \qquad (P - k)f' - r_2 - r_4 = 0.$$

The tax on effort that will turn the open-access condition to the optimal condition is

$$(11) \quad t_e = (P - k)\left(\frac{f}{E} - f'\right) - \left[s(P - k)\,\frac{f}{E} - r_2\right].$$

The first term of this tax is analogous to the tax on effort in the traditional model (Anderson, chap. 4). At the optimal level of E, it is the total value of rent earned per unit of effort. The second term, at the optimal level of E, represents the rent per unit of effort earned by crew members given the fixed share rate. In essence, the optimal tax on boat owners is their per unit rent at the optimal level of effort, since the tax is the difference between the total per unit rent earned and that part which goes to the crews. It is not necessary to tax all rent away from boat owners, because given the fixed share rate, some of it goes to the crew. As far as boat owners are concerned, it does not matter whether the rent goes to the government or to crew members. They do not get it, so it can not be an incentive to overproduce effort.

In the presence of this tax, the open-access equilibrium of vessel owners will be at the optimal level of effort. Although they will not be earning rents, crew members will. This means that individuals will try to find work as crew members in order to obtain some of this rent. However, given the tax and the fixed share rate (GLN specifically assume that the share rate will not change), they will be unable to find positions.

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Optimum Effort and Rent Distribution in the Gulf of Mexico Shrimp Fishery: Reply

Wade L. Griffin, Ronald D. Lacewell, and John P. Nichols

Anderson has very appropriately pointed to three errors in our article and corrected them in his comment. We appreciate his thoroughness. However, there may still be a misconception that needs clarification.

The statement to which Anderson refers in our article, "When crews receive a fixed share of gross returns, labor cost are proportioned to catch . . ." is a true statement. Anderson states that "this is only true for pecuniary or financial costs. In their model the opportunity cost of labor is not affected by the way revenues and/or cash costs are shared." We are in total agreement with his statement. This is the key to our analysis and is, therefore, the very reason rent accrues to crewmen. Under the assumption of fixed shares, as a fishing industry moves from an open-access equilibrium to a level of effort that maximizes rent, the vessel owner must indeed pay financial cost to the crew, not the opportunity cost of their labor. Rent to the crew is the difference between the financial cost paid to them by the vessel owner and the opportunity cost for their labor which, as Anderson says, does not change. Hence, our original statement stands: when crews receive a fixed share of gross returns, labor cost, not opportunity cost of labor, are proportional to catch; therefore, rent accrues to crew members as well as vessel owners under limited entry.

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The Impact of Component Pricing of Soybeans and Milk: Comment

William H. Lesser

Perrin, in a recent article in the *Journal*, presented a useful model for analyzing the equilibrium price, quantity, and welfare effects of instituting component pricing for agricultural products heretofore sold on a commodity basis. This model was applied to data on soybeans and milk, leading in both cases to the conclusion that the social benefits from component pricing of these commodities are small (p. 454). The application to soybeans appears well conceived and the results reasonable (see also Updaw). The use of the same model to analyze the effects of component pricing of milk, however, contains a significant perceptual error which biases the estimated equilibrium effects toward zero. The purpose of this comment is to identify this error and its effect on conclusions about the economic efficiency of component pricing for milk. To set the stage for this discussion, the Perrin model is briefly reviewed.

Perrin Model

The model is based on the (exogenous) shift in the value of ρ following a change from commodity to component pricing. Here,

$$\rho = (w_a/w_b)/(p_a/p_b),$$

where w_a and w_b are the prices received by producers for components A and B, respectively, and p_a and p_b are the consumers' prices for A and B. With component pricing and perfect measurement of A and B, $\rho = 1$; while for commodity pricing, ρ may take any positive value. The displacement effect of the adjustment from the commodity value of ρ to the component value then changes the equilibrium quantities of A and B. Since the model is based on a linear homogenous production function, the estimated price, quantity, and welfare effects are linear functions of ρ, which is defined in terms of percentage changes (pp. 445–48). The results thus depend critically on the estimated value of ρ under commodity pricing. It is here that I take exception with the application of this model to milk.

Component Pricing of Milk

Applying the model to milk, Perrin recognizes two components of milk—fat and solids-not-fat (SNF) (mostly protein and lactose). Values under commodity pricing for w_a and w_b and for p_a and p_b are approximated as follows (pp. 452–53):

Producer price for butterfat (w_a): the per pound value of the average premium for milk over the average of butterfat in excess of 3.5%, the base value used in federal order pricing.

Producer price for SNF (w_b): the remaining value of milk net of butterfat payments is imputed on a per pound basis to SNF produced.

Wholesale price for butterfat (p_a): average price paid for butterfat.

Wholesale price for *SNF* (p_b): average price for nonfat dry milk. For 1974–76 the estimated values lead to a calculated ρ value as follows:

$$\rho = \frac{.882/.63}{.77/.61} \simeq 1.17.$$

Hence, a shift to component pricing would result in 17% reduction in ρ (pp. 452–53). Because this change in ρ is relatively small, the estimated welfare effects of a change to component pricing are small also.

Perrin's calculation of ρ is, however, biased toward one. The source of the bias may be seen in figure 1, which is a three-dimensional generalization of Perrin's figure 1 (p. 446). Here, milk is depicted as consisting of three components: fat, SNF, and the residual fluid carrier. The production possibility surface is labeled PPS. Now current pricing practices in all Federal Milk Market Orders and most state orders (but not California) price separately as two products, fat and the residual. The latter is referred to as skim milk. This amounts to combining SNF and the fluid carrier so that the figure 1 surface collapses into a two-dimensional frontier with the axes identified as "fat" and "skim milk." To calculate value for ρ, Perrin also prices fat and the residual, which he labels SNF. Thus, his PPS also collapses to a frontier with axes labeled "fat" and "SNF." This curve is depicted as component pricing ostensibly because the term SNF is used rather than skim milk. However, the pricing systems are identical and only the axis labels are changed. Hence, the ρ estimated by Perrin for

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Jim Pratt commented on an earlier draft.

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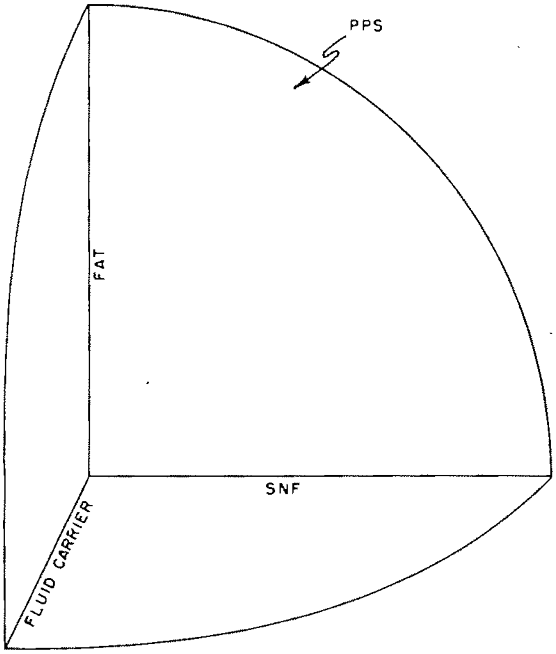

Figure 1. Components of whole milk

commodity pricing is really measuring how efficiently markets are working to balance production between fat and skim milk in relation to demand and production elasticities. That the resultant value is close to one is comforting but hardly interesting.

True component pricing would value (at least) the three components in figure 1 separately. Since fat can literally be removed, this problem will reduce to two dimensions to fit the Perrin definition of ρ. Although this is trivial, it requires a valuation of the fluid carrier at both the farm and consumer levels. At the producer level, no separate price for this product exists in federal order markets. (The California State Milk Market Order prices a fluid carrier for Class I milk only, and this value reflects the class premium.) For handlers, on the other hand, the value of the fluid portion depends in part on the end use. With fluid and some soft products, the fluid carrier is an integral part. For hard products, much of the fluid component has little value, and might even involve a disposal cost. The same is true for powder producers who must evaporate the liquid. Thus, the consumer value of ρ under true component pricing varies by products and is difficult to estimate in all cases.

Nevertheless the distribution of SNF in milk can provide some insights into the magnitude of the bias in the Perrin estimate. This may be done by assuming that the upper extent of the 95% confidence interval for SNF production is achievable. Grappin, Packard, and Ginn provide an estimate of the interval from a random sample of Minnesota and Wisconsin herds. Using their data, the confidence interval is estimated to be 8.90% ± .059 (p. 70). Although these herds are located in one region, the closeness of the estimated average to the 8.61% figure used by Perrin provides some assurance that the Midwest data do not depart greatly from national values.

With a yield of 8.95%, the farm value of SNF is estimated to be $:628, which is not sufficiently different from Perrin's value of $.630 to change the value of ρ.

However, the assumption that the upper bound of the 95% confidence interval is the maximum achievable may be too limiting. It is possible that with an economic incentive to expand SNF production it could be done. For example Cropp et al. have found that the SNF content can be affected by the seasonality of the production and the point in the lactation cycle when the milk is collected (p. 8). This has led to at least one analysis of the efficiency of collecting milk in two separate tanks at the farm (Fife and Carr pp. 9–10). Additionally, the SNF content is a breed characteristic with Jerseys showing higher levels than Holsteins (*Equity Handbook,* p. 7).

Grappin, Packard, and Ginn provide data for estimating a higher achievable level of SNF. They analyzed milk samples, again from the upper Midwest, selected to reflect different breeds and estimated a 95% confidence interval of 9.06% ± .055. With a yield of 9.115% the farm value of SNF is estimated to be 61.8¢ per pound. Reestimating ρ using the remaining values as presented by Perrin gives $1.43/1.2 = 1.19$. This value, too, is close to the 1.17 figure presented by Perrin, and the slight difference given the crudeness of the figures used is probably not meaningful. Thus, while the expected direction of bias has been observed in the Perrin results, the magnitude appears insignificant. However, the insignificance of the result may be a characteristic of the sample which contained 70% pure Holstein herds (p. 69).

Other economic advantages exist for high SNF milk for use in some products. Higher SNF contents, and hence higher yields—a .1% increase in protein composition increases the average herd product output by .28% (Nilson, Partridge, Webster)—reduce the bulk transport costs to the handler and costs associated with the removal and/or disposal of the surplus liquid. Presently a few cheese plants are paying for milk on the basis of its estimated cheese yield (Ernstrom, p. 1024). Potentially greater savings will be available in the future as selective breeding is utilized to increase SNF yields (Bernard).

Conclusion

An error in formulating the displacement effects of a movement from commodity to component pricing of milk has been shown to bias Perrin's estimate of ρ toward one. Limited available data on the variability of the SNF content in milk support the existence of this bias, but the magnitude appears small. However, more complete data are required before a final judgment can be made about the social returns to component pricing for milk. It would be unfortunate if an error in the Perrin model delayed this important research.

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The Impact of Component Pricing of Soybeans and Milk: Reply

R. K. Perrin

The main point of Lesser's comment on my article seems to be that in the case of milk my procedure for estimating ρ biases the estimate toward 1.0. If true, the subsequent analysis would have underestimated both the size of equilibrium shifts caused by a change to component pricing and the increase in social surplus which would follow from such a change. Lesser offers three diverse reasons for the existence of bias in my estimate $\hat{\rho} = (w_a/w_b)/(p_a/p_b) \simeq (.882/.63)/(1.2) = 1.17$. First, in paragraph 4, he states that his figure 1 shows how my use of a two-component model for a three-component situation produces such a bias. Second, in paragraph 5, he states that for some processors the marginal value product of the residual approaches zero, which would imply a large value of ρ. Third, in paragraphs 6–9, he notes that in estimating the farm value of SNF (w_b), the residual value could be imputed to larger quantities of SNF, and if so the estimate of w_b would fall and the estimate of ρ would rise. The latter two arguments are fallacious, so I will address them first, then turn to the first argument, which has some substance.

One must have an estimate of the implicit producer price of SNF (w_b) to estimate ρ. I subtracted the value of fat (at \$.882 per pound) from the total producer value of milk and imputed this remainder to the 5.98 billion pounds of SNF produced to obtain $w_b = (\$3.773)/(5.98) = \$.63$. It is clear that if 5.98 is an underestimate of SNF production, then \$.63 is an overestimate of imputed price, and 1.17 is an underestimate of the implicit disequilibrium. Lesser offers no evidence in his note that 5.98 is an underestimate. In paragraphs 6–9 he suggests that some cows under some conditions can produce a higher-than-average percentage of SNF, but of course, by the same token, others must produce lower-than-average levels. The estimated 5.98 billion pounds of SNF is unaffected by such observations about the distribution of SNF in milk, so the imputed average price of \$.63 must also be unaffected.

Lesser argues in paragraph 5 that for some processors, the marginal value product of nonfat components might be very low. But even if true, this assertion has no effect whatever on the imputation procedure (above) by which both he and I determined w_b. If anything, his assertion would suggest that my estimate of p_b (the SNF price in the component market) is too large. But this would imply an upward bias in the estimate of ρ, which is exactly the opposite of what Lesser wanted to prove by the assertion.

Finally, let me turn to Lesser's fourth paragraph, in which it is asserted that "the source of the bias may be seen" in figure 1. No matter how hard I look, I cannot see it there, but I do think there is support for Lesser's hunch that ρ is underestimated. The intent of my earlier analysis was to examine adjustments in just the fat-SNF plane of figure 1. At first glance this seems to be a legitimate exercise if one has a reasonable estimate of the four prices which apply to that plane (w_a, w_b, p_a and p_b). The conclusions would be incorrect only to the extent that adjustments along the third (omitted) axis would affect adjustments in the fat-SNF plane. But the situation is really worse than that. In assuming that fat and SNF are the only two components, one must impute the entire value of milk to these two components, with the result that the implicit producer price for SNF is \$.63 per pound as indicated above. Yet, the producer really has no more incentive to produce SNF than to produce any other nonfat component. If the residual value of milk (after deducting the value of fat) is imputed to the entire nonfat residual, we find this value to be \$.056 per pound. This is probably a more appropriate estimate of w_b, the implicit incentive for producers to produce an additional pound of SNF under the current pricing structure. Such a value for w_b results in a value of ρ of about 13, which is spectacular support for Lesser's assertion that a value of 1.17 is too low. It implies that there is a very large implicit disequilibrium in fat-SNF space.

So, I think that Lesser is correct in warning that my analysis contains conceptual problems which probably resulted in an underestimate of the potential impact of component pricing in milk. Unfortunately, the two-component model will not accommodate an analysis with the value of w_b at \$.056 rather than \$.63, because the shares of fat and SNF in this case would sum only to .43 of the farm value of milk rather than 1.0 as is assumed by the model. One could attach no significance to the results even if the calculations were made. There seems to be no way to evaluate the significance of Lesser's insight until a three-component analytical model is available. Work on such a model is nearing completion here, and we hope to be able to reexamine this issue in the near future.

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Books Reviewed

Clawson, Marion. ***New Deal Planning: The National Resources Planning Board.*** **Baltimore Md: Johns Hopkins University Press, 1981, xxii + 356 pp., $32.50.**

The author, a distinguished public servant in the federal government, served for several years as the director of the Bureau of Land Management in the Department of the Interior and since 1955 has been closely associated with Resources for the Future. This book is the result of his careful study of the National Resources Planning Board in its four somewhat different guises in the years from 1933 until its congressional execution in 1943. Although Clawson did not serve on the staff of the NRPB, he was a member of various committees and knew much about the Board's functioning. He has read extensively and consulted widely in undertaking this telling of a particular episode in providing a planning mechanism at the center of federal government executive structure.

After an opening chapter entitled "An Overview," Clawson divides his account into five parts: "Origin and Setting"; "History, Organization, and Operation"; "Substantive Fields and Activities"; the "NRPB in the Structure of American Government"; and "Demise and Legacy." The study necessarily involves economic history, political history, and a history of the role of ideas in a critical ten-year period of the United States. Inevitably in so ambitious an endeavor, there are peaks and valleys of insights, understandings, and judgment.

From my own limited experience as a staff member of the NRPB for fifteen months in 1941–42, I am disposed to say that Clawson has been knowledgeable and objective in his assessment of the structure, the personalities, the accomplishments, and the deficiencies of the Board. Throughout the study the author stresses two important themes: the development and stimulation of ideas about the American economy and the governmental role therein, and the effort to promote planning coordination as a political/administrative process. He is inclined, properly I believe, to give the NRPB high marks for the development of ideas and lower marks for its achievements in the coordination of planning processes. It was, of course, as a governmental agency encouraging governmental action in a failed economy that the NRPB generated ideological controversy and so contributed heavily to its extinction in the middle of World War II.

On the substantive side, Clawson asserts that the NRPB played a "highly important role" in the development of ideas and procedures about natural resources planning, and especially about land-use and water-use management. Indeed, Clawson asserts that if the agency had confined its role to studies of natural resources it might have been fully as effective and have survived longer (p. 124). Of the studies about population, housing, research, and welfare and security, the author observes both the political implications and the political repercussions of these reports. Of the studies about public works as an instrument of governmental economic intervention, about consumer incomes and expenditures, about industrial location, and about full utilization of economic resources, Clawson acknowledges their contributions to an economic debate quite different from the issues of our own day. Of the studies about transportation policy and urban structures the author says only that they illustrated the wide range of the Board's interests and activities.

It will come as no surprise to those who know of Clawson's own career if this reviewer finds the treatment of land-use and water-use programs to be more extensive and more incisive than his treatment of other studies of the Board. Clawson also gives the NRPB appropriate credit for advancing the practice of urban and regional planning in the United States. It is in dealing with some of the political aspects of planning that Clawson appears somewhat hesitant.

Apart from historical usefulness, the reader will probably be especially interested in Clawson's final five chapters, which deal with the end of the National Resources Planning Board, its legacy, its appraisal, and the utility of the Board as a precedent for present governmental structure. This reviewer believes that Clawson underrates the role of the Council of Economic Advisers and of the Domestic Council as agencies which can perform much of the work once done by the NRPB, and the author ignores the importance of the ad hoc presidential agency, such as the recent President's Commission for a National Agenda for the Eighties, as a stimulator of ideas.

Reviewers are ever disposed to want authors to write the kind of book the reviewer would like to write, if he only had the time and the competency. This reviewer is no exception to the rule. I have been intrigued by Clawson's attention to the role of ideas as a stimulator of political action. Unfortunately, we know very little about the extent to which ideas do in fact motivate and determine individual and institutional behavior. It seems to me that our current models of economic and governmental behavior are rather far removed from the realities of a nation and a world confronting finite resources and infinite expectations. None can deny our continued apparent inability to deal effectively nationally and globally with inflation, unemployment, and persistent poverty. The despair and hope

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of the 1930s appear simplistic in contrast with the harsh limitations of thought and deed in the 1980s.

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Ghatak, Subrata. ***Technology Transfer to Developing Countries: The Case Study of the Fertilizer Industry.*** **Greenwich CT: Jai Press, 1981, xix + 181 pp. $28.50.**

Because the fertilizer industry provides a key input for agricultural development and also a nucleus for broad-based chemical industry, its unique role in economic development of the less developed countries (LDCs) has long been understood.

Several developments make a book on transfer of technology to the LDCs in the case of the fertilizer industry timely. Between 1950 and 1980, fertilizer consumption of LDCs increased from about 1 million metric tons (mmts) to nearly 32 mmts. In only 6 years after the oil crisis of 1973/74, LDCs raised their fertilizer consumption by about 13 mmts. This increment far exceeds the growth in total world fertilizer consumption during the first century of its use and accounts for as much as 45% of the growth in it after 1973/74. There is growing evidence on the substantial contribution of fertilizer to the past growth in agricultural production of LDCs. The complementarity between biological breakthroughs in crop production and high rates of fertilizer application also points up its importance. Because of all these, the need to sustain rapid growth in fertilizer consumption of LDCs is widely recognized. Fertilizer production in the LDCs has lagged behind consumption. This plus the impact of the oil crisis on the economics of the fertilizer industry and the presence of fertilizer raw materials and feedstocks in many LDCs further strengthen the case for rapid development of the fertilizer industry in LDCs.

The book under review begins with a chapter on growth, technology transfer, and environment in the LDCs. Its central theme is that the impact of technology transfer on the environment in the LDCs should be examined by considering the development process primarily a matter of raising per capita real income, and environmental degradation as one of the prices paid for that process. The remaining chapters are on production and consumption of fertilizer, structure of technology supplying industry, case studies on the transfer of fertilizer technology, economic aspects of the fertilizer industry, the impact of fertilizer technology on environment, and alternatives to fertilizer technology.

Some major findings and conclusions of the book are as follows. The importance of fertilizer to the LDCs cannot be denied, alternatives to fertilizer technology notwithstanding. Many LDCs would be better off by producing rather than importing fertilizer in the long run. Profitability, however, would depend upon speedy execution, capacity utilization, plant size, proper maintenance, and demand for the product. Where the size of fertilizer market is the constraining factor, LDCs may derive higher social net benefits by forming customs unions. Although there are physical, social and health hazards associated with fertilizer production, pollution from fertilizer plants can be minimized at relatively low cost if various controls are correctly applied. There is considerable overlap between plant constructing companies and process patent owners in the fertilizer technology supplying industry. But there is no hard evidence to conclude anything about oligopolistic or monopolistic control.

Despite certain shortcomings, such as exclusion of the research on technologies of biological nitrogen fixation from the consideration of alternatives to fertilizer technology, lack of consistency in the data presented in chapter 3, and excessive weight to the Indian experience in drawing general conclusions, the study clearly brings out the importance of fertilizer to the LDCs. Nor can one deny the merit of its approach to and conclusions about the impact of fertilizer technology on the environment in the LDCs. Similarly, the information on the nature of the fertilizer technology supplying industry is both interesting and useful.

But as a study on the transfer of technology to the LDCs in the case of the fertilizer industry, the book is disappointing. To gain insights into this process, which has been mentioned repeatedly in enumerating the advantages of the LDCs as "the late comers," and also to draw meaningful lessons for further development of the fertilizer industry in the LDCs, questions such as these are crucial: Which factors have governed the past growth of fertilizer industry in the LDCs? Has the transfer of technology reduced the technological dependence of the LDCs on the developed countries in further developing their fertilizer industry? Has the development of this industry provided the nucleus for industrialization of the LDCs, or has it only raised their fertilizer production? The fertilizer industry in the LDCs has come a long way in the last three decades. More significantly, the past experiences of different developing countries (notably China, India, Brazil and some smaller countries) have been varied enough to throw useful light on these questions. It is unfortunate that the book under review completely bypasses them.

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Harsh, Stephen B., Larry J. Conner, and Gerald D. Schwab. ***Managing the Farm Business.*** **Englewood Cliffs NJ: Prentice-Hall, 1981, xv + 384 pp., $18.95.**

The authors state rather clearly the group they intend to address: primarily, undergraduate students in farm management. An undergraduate text should provide the core of the subject matter content for the course. Also, it should assist in providing an organization for the course to give some assurance of a systematic coverage of the material. An introductory farm management text carries the added responsibility of bridging the gap between abstract economic principles and the practical application of these principles.

For many students, this book represents their only course in farm management. The major objectives probably would be to give the student the ability to do effective planning, both on a partial and a whole farm basis, and to be able to deal with record systems that provide the basis for analyzing the business and fulfilling the legal needs. The students should also gain an awareness of the potential benefits and pitfalls associated with tax management and the use of credit, to the extent that they will be able to recognize problems and seek qualified help. Time and page space quickly become a limiting factor for a single volume or a single semester course. Content becomes a matter of trade-offs and priorities. In the context of the above objectives, it appears that this book does the job very well. It is generally organized along traditional lines.

The book is divided into five parts, an "Introduction," "Descriptive Analysis," "Diagnostic Analysis," "Prediction," and "Prescriptive Analysis," consecutively. The first three parts deal with the role of management, economic concepts, farm record systems, farm business analysis, and forms of business organization.

Part 4, "Prediction," deals with planning techniques on both a partial and a whole farm basis and makes up a major portion of the book. It also deals with resource control and investment analysis, as well as with labor and machinery, tax management, and risk and uncertainty. The section is concluded with an excellent discussion of the normal development pattern found in a family farm business, starting with initial development and growth, going through the maturity plateau, and ending with liquidation and retirement.

The final section of one chapter, dealing with "Prescriptive Analysis," is a general discussion of management and decision making. The authors indicate that many teachers may wish to integrate this part with part 1. Indeed, one is left with the question of why it is not in part 1.

There are two overall weaknesses in the book, not unique to this text. First, although the authors acknowledge the role and importance of the enterprise budget in several places, they devote less than one and a half pages of copy and one page of examples to enterprise budgets. The second weakness is the failure to relate more explicitly the various economic concepts in the planning and decision process. Inasmuch as the enterprise budget is the basic building block of all planning and partial budgeting, it seems that the ability to develop and evaluate properly an enterprise budget may well be the most important single phase of the management process the beginning student should learn. It is in the enterprise budget that economic concepts generally find their practical application. It is difficult to overemphasize the importance of the enterprise budget, however casually it may be accepted.

For a basic farm management text, the chapter on capital budgeting is quite complete. There is, however, no direct reference to the risk of a high debt/equity ratio in the uncertain world of price and yield variability (as a result of heavy credit use). The importance of consulting specialists with financial or legal skills and experience should be emphasized.

In my opinion, risk and uncertainty should be considered in tandem with economic concepts. This would lead the student from the environment of perfect knowledge to imperfect knowledge as farm business planning is approached.

These comments reflect only one person's set of priorities concerning education in farm management, of course. The book is written in a straightforward manner. Students, for the most part, should be able to follow it with few problems. Some of the examples may be confusing to the student, but they are probably no more than one would expect to find in any journalistic undertaking of this type. A technique which many students should find helpful is the authors' use of one farming situation (Casey Farmer's) throughout the book, thereby enabling the student to tie the examples together as they progress through the course. This book should find wide acceptance among beginning farm management classes.

Robert L. Johnstone
Berea College

Kamien, Morton I., and Nancy L. Schwartz. *Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management.* New York: Elsevier North-Holland Publishing Co., 1981, xi + 331 pp., $32.95.

This is probably the best text now available for students of economics and management sciences to learn the elements of deterministic dynamic optimization. By adopting simplifying assumptions, the authors have been able to achieve a readable, self-contained exposition of this material. The book consists of thirty-nine sections, each containing worked examples and exercises and appropriate to one class hour. Five brief appendices cover necessary background material, such as Green's theorem in the plane and existence theory for ordinary differential equations.

The text covers both the classical calculus of variations and modern optimal control theory and explains the connection between them. The maximum principle, Euler-Lagrange equations, transversality, singular solutions, elementary sufficiency theorems, and impulse controls are among the topics addressed. The final three sections, on time-lag systems, dynamic programming, and stochastic optimal control are, in my view, too cursory to do justice to these more difficult topics.

The applications discussed are chosen to illustrate the theory, and not to provide a coherent account of any area of mathematical economics. Capital theory and economic growth constitute threads running through the applications, however.

While pedagogically sound, the simple approach used in this text tends to underplay the difficulties that can arise—and often do—in practical applications. The student should be warned that simplistic attempts to extend the theory outlined here may not work; the applied optimization literature already contains many blunders resulting from the failure to appreciate this fact.

Colin W. Clark
Department of Mathematics
University of British Columbia

Labys, Walter C. ***Market Structure, Bargaining Power, and Resource Price Formation.*** **Lexington MA: Lexington Books, 1980, xiv + 238 pp., price unknown.**

In the wake of the OPEC shock and the Group of 77s demands for a New Economic Order, international commodity markets again become a prime target of economic research. One thrust of the analysis explored possibilities for stabilizing revenues and prices through compensatory finance schemes and buffer stocks. The most sophisticated work applied control techniques to econometric models of world commodity markets. The whole enterprise was subject to the (probably fatal) critique raised by Robert E. Lucas, Jr., Thomas Sargent, and others in a macroeconomic context: the introduction of stabilization schemes will affect the behavioral parameters of the econometric model in ways not explicitly specified within existing models (for example, buffer stocks will change the behavior of private speculators). Thus the results of policy exercises manipulating such econometric models will be systematically biased.

Another line of research weighed the likelihood of producer cartels in raw materials and the appropriate policy responses of consumer nations. The best work here probably was the very thorough industrial organization studies of primary metals which Charles River Associates completed in 1976–77 for the National Bureau of Standards.

Finally, some work focussed on longer-term issues of minerals development, including ways in which the expertise and financial capital of the industrial world could be channeled efficiently into the exploration and development of minerals in increasingly nationalistic but resource-abundant LDCs. Raymond Mikesell, among others, was a significant contributor.

In the past, Labys has been a modeler and stabilizer, but his latest book is very much in the spirit of the last two research areas. The book contains a wealth of information on the structure and operation of international markets for four of the most important minerals. Trends in market concentration, pricing and contractual procedures, marketing and processing channels, mining investment costs, sources of capital, relations between host country and multinationals, production, trade, consumption, and technology are all set forth with just about the right amount of detail and with some attempt to assess their implications for price formation. The book succeeds as a very useful reference or introduction to the international economics of copper, tin, bauxite, and iron ore.

This, however, was not Labys' main purpose. Rather, he was seeking "to develop a framework or methodological approach to mineral price analysis" (p. 3). His framework turns out to be F. M. Scherer's structure-performance approach, augmented by factors of special relevance to LDCs or minerals—export dependence, resource control, etc. While this is a perfectly reasonable way to go, Labys tends to make too much of what is now a fairly standard approach. The framework chapter is both too long—and too short. So many topics are covered that few are explained in much depth.

The chapters on the four minerals are more interesting. Labys breaks no new ground here, but instead organizes a great deal of secondary material in an enlightening fashion. One two-page table near the end of the book manages to summarize the important structural characteristics and their trends with admirable directness.

Among the more important conclusions: minerals markets are becoming more competitive (exception: bauxite), although still characterized by oligopoly-oligopsony structures. Host countries have extended their control over natural resources and their share of the rents, but Labys seems to believe that the worst confrontations are over, with the future bringing more cooperative relations between governments and multinationals. Although Labys was initially motivated to undertake this study by a desire to determine whether market prices in fact reflect true economic value (p. 2), he does not really attempt a systematic answer to that very important question.

The text is not error-free. For example, Labys states that price fluctuations in copper are linked to "the relative inelasticity of supply response compared to demand response" (p. 100), when in fact the larger the demand elasticity, given the supply elasticity, the smaller the price change provoked by shifts in demand or supply. The derivation of the tax-minimizing allocation of profits between overseas subsidiary and U.S. parent is a bit garbled (p. 160), although the final results are correct.

Some sections of the book, especially the framework chapter, could have benefitted from a rewrite. Even so, those interested in a concise and, in the last analysis, well-organized introduction to the economics of the four minerals markets would be hard-pressed to find a better single source.

Gordon W. Smith
Rice University

References

Policy Implications of Producer Country Supply Restrictions. Cambridge MA: Charles River Associates, 1976–77.

Scherer, F. M. *Industrial Market Structure and Economic Performance.* Chicago: Rand-McNally & Co., 1970.

Uchtmann, Donald L., J. W. Looney, N. G. P. Krausz, and H. W. Hannah. *Agricultural Law: Principles and Cases.* New York: McGraw-Hill Book Co., 1981, xxiv + 664 pp., $24.95.

The laws that affect the farmer and rancher are brought to life by this textbook. The reader is introduced to the laws by edited cases interspersed with treatise-type discussion of the laws. This format gives the reader a general idea of the principle of a particular legal issue without giving the impression that the principle is set and never-changing.

The book is well-suited for its primary audience—students in their final year of undergraduate study. The purpose of most agricultural law courses for those students is to teach them to recognize the legal problems they may face in their careers so that they can deal with them early and minimize their impact. This book facilitates that purpose not only by discussing the rule of law that applies to a particular situation but by motivating the student's interest with a real-life factual situation. Since college seniors usually do not have enough real-world experience to know the questions to be asked about a great variety of legal issues, the motivation provided by this book is a major contribution to the field of teaching undergraduate agricultural law.

The book is national in scope. It discusses the laws of the fifty states generally and illustrates the discussion with the rules of particular states. This feature is a strength of the book as well as a limitation. It is a strength in that it shifts the emphasis from the actual rule of law to the process by which laws are made. By not limiting its scope to one state's laws, the authors have made the book equally useful in all fifty states.

The national scope of the book is a limitation in that the best motivation for a student is to realize that the law being discussed will affect him or her. Therefore, as the authors probably intend, the book needs to be supplemented with material (either written or oral) about the laws of the state in which most of the students will pursue their careers. The authors suggest in the preface that particular topics be omitted in states where they are not significant. An instructor using this textbook needs to have a good understanding of the laws of the state in which the course is taught or have a good set of materials that explain those laws.

The authors have appropriately organized the book by typical agricultural activities rather than by traditional legal subject areas. For a lay student of the law, the legal distinctions of subject matter are not important. The use of agricultural activities to organize the material does create some logistical problems, however, because some legal topics are common to several agricultural activities. For example, torts arising from keeping animals are common to both land ownership and raising livestock. The authors have discussed nuisance actions arising from lifestock in chapter 7, "Rights and Limitations in the Use and Ownership of Agricultural Property." Fence laws and trespass by animals are discussed in chapter 10, "Farm and Ranch Animals." Therefore, to understand the tort liabilities faced by a person who keeps livestock, parts of more than one chapter must be covered.

The logistical problem of organizing the book by agricultural activity is minimized by including three useful features in the book. First, there is a detailed table of contents that tells the reader at a glance what topics are covered in each chapter. Second, there is a fairly complete index with both legal and agricultural activity topics included. Finally, there are study questions at the end of each chapter to help the reader realize that all the law affecting a particular agricultural activity may not be covered in that one chapter.

For its primary audience, upper class undergraduate students of agricultural law, this book could be used as the main text or as supplemental readings for another text. In addition to its primary audience, this book would be useful as a reference book for people working in the agricultural sector. Law students may find this book useful for giving them an idea of the type of legal problems their future farm clients will face. For any of these readers, the combination of edited cases and discussion of the law will create an appreciation for the ability of laws to solve some problems faced by farmers and the limits on that ability.

Philip E. Harris
University of Wisconsin

Vogeler, Ingolf. *The Myth of the Family Farm: Agribusiness Dominance of U.S. Agriculture.* Boulder CO: Westview Press, 1981, xix + 352 pages, $25.00.

The author of this book, a professor of geography, presents a perspective on the structure of American agriculture that combines his economic, social, and political values.

The book is divided into six parts and fourteen chapters. The first part deals with farm structure and the view that an agrarian crisis exists from the perspective of family farmers and landless agricultural workers. Part two sketches early land and water distribution policies and the author's views on their failures to establish a true family farm system. Part three discusses the market economy and agribusiness, economies of size, vertical integration, contract farming, and the lack of social justice in the U.S. agricultural structure. Part four discusses tax loss farming, federal farm programs, and the land grant college system. Part five covers the plight of seasonal farm workers and their families and the decline of small towns dependent upon agriculture. Part six concludes with a brief history of progressive and farmer protest movements along with a structural analysis from a labor theory of value orientation.

Vogeler includes in the appendix thirty-nine organizations "working for progressive rural change." The list includes only two of the established general farm and commodity organizations with producer members.

He sees capitalism working well for some but not for the remaining family and tenant farmers, agricultural workers, food consumers, and small towns dependent on agriculture. He wants a system that provides higher returns to labor and lower returns to capital and management, in essence, a new "populism."

Vogeler's insistence that all returns go only to labor reveals his lack of understanding of the total food and fiber system. He does not mention any distribution of returns to managers, land, and capital suppliers, marketing firms, and off-farm labor that contribute to the operation of the total system. His perception is illustrated by the statement, "The value they (workers) produce (above their wages) goes to the capitalists . . . which in conventional terms is profit" (p. 285).

One of the sources of confusion and distortion that shows up frequently is the author's lumping all agricultural production from larger farms as part of the agribusiness complex and blaming all the problems of small and modest size farms upon agribusiness and the larger-volume, and usually more profitable, farming operations.

Throughout the book he is critical of the institutions in the food and fiber system that have evolved, but at no place does he suggest alternatives to resolve what he sees as problems with the present system.

Critical of current advanced technology, he believes that all benefits of technology accrue to large farmers and agribusiness firms. He does not recognize any benefits to consumers in terms of cost or availability of food, or benefits to society.

One of the overriding issues that Vogeler fails to discuss is to what extent policy decisions should facilitate industrialization of the entire food system with its associated quality and quantities of food, and to what extent policy decisions should be based upon social and noneconomic considerations. His most valid point may be that more research and education could be done to assist workers displaced by mechanization.

The author sees family farmers as having more in common with other workers than with larger farmers and agribusiness firms. He seems to resent that many farmers see themselves more aligned with the interest of larger farmers and other businessmen than with farm workers and other laborers. He sees the solution "in progressive farmer-labor alliances." He suggests that alliances of consumers and farmers could lower food costs and raise agricultural prices by sharing "a fraction of the immense profits made by the food industry" (p. 296).

Vogeler recognizes that family farmers have three distinct sources of income as owners of land, capital, and labor. But he seems to resent their combined sources of income because his Marxist perspective tells him that these sources represent three conflicting social classes (p. 287).

He also seems unaware that average incomes of the farm population were higher than the nonfarm population in 1973 and 1979, that the Agriculture Foreign Investment Disclosure Act of 1978 now makes information on foreign land ownership available, and that land can be rented by crop-share lease.

His perspective on the land grant university system is based on the reports of mechanization research that has led to new technology and replacement of farm workers, on an incomplete picture of the scope of the cooperative extension service, and complete omission of the resident teaching and graduate education programs.

He states that under conditions of agrarian capitalism, radicals see agribusiness and family farmers as representing opposing classes and perspectives united in one contradiction (p. 291). Since this is his perspective, Vogeler has described himself.

I would have a less critical evaluation of this book if the author had not mixed his citations of scholarly efforts by agricultural economists with reports and writings of journalists whose value systems are not known or are biased to favor specific social or political interests.

Without doubt Vogeler presents a perspective of family farming different from that of most agricultural economists. But I wonder if he has met many of today's family farmers.

Harold D. Guither
University of Illinois

AAEA Awards Program

Through its awards program the American Agricultural Economics Association recognizes professional excellence in agricultural economics. Awards are made for professional achievement at the student, the young professional, and the more experienced levels in research, teaching, and extension activities. Awards are presented at the Awards Program during the annual meetings of the AAEA. Recipients are identified in the awards program brochure and in the December proceedings issue of the *AJAE*.

Selection of Fellows

In recognition of distinguished contributions to agricultural economics, the title "Fellow of the American Agricultural Association" may be conferred. The main consideration in the selection of individuals for this honor shall be continuous contribution to the advancement of agricultural economics. Achievements may be in the field of research, teaching, extension, administration or business.

Nomination

Any member of the Association may nominate any living member for the honor of election as Fellow by submitting the name to the Secretary Treasurer of the Association. Any member making a nomination should submit biographical information in twelve copies of no more than eight pages each in support of the nominee. A nominee must be a current member of the Association in good standing or have been a member thereof for at least ten years.

Candidates

The Executive Board of the Association shall select candidates from the nominees (approximately twice the maximum number to be elected) and present the list of candidates to the Fellows Election Committee of the Association together with supporting biographical data for each. The Fellows Election Committee shall be composed of five Fellows and a designated representative of the Executive Board.

Election

The Fellows Election Committee shall select the Fellows, not to exceed four in any one year, from the nominees submitted by the Executive Board of the Association. The Chairman of the Fellows Election Committee shall report to the President and the Secretary Treasurer of the Association at least 60 days before the annual meeting the names of the newly elected Fellows.

Announcement of Election

The names of the newly elected Fellows shall be announced at the annual meeting of the Association by the President of the Association or his appointed representative, who shall read a statement regarding the achievements of each Fellow and shall present a certificate of recognition to the person so honored. The statements regarding achievements will be published in the December proceedings issue of the *AJAE*.

Distinguished Extension Programs

The distinguished extension program awards recognize achievement of excellence in extension economics teaching programs. Two awards may be given. One of the awards is to be given to an individual. A second award may be given to a group of two or more extension workers. The name and contribution of each person must be identified in any group nomination.

Nomination

Nominations may be made by any member(s) of the AAEA, and selection will be made from among those nominated. A nominee must have been active in extension teaching for at least one year at the time of the nomination, and the content of teaching efforts must be principally in the field of agricultural economics. Each nomination must be made by separate letter accompanied by eight copies of documentary evidence including nominee name(s) and extension title(s); extension program area in which teaching is conducted; identification of the clientele served; objectives of the educational program, teaching techniques, educational methods, and materials utilized; and effectiveness of the extension teaching effort in terms of clientele response and/or establishment of the utility of the extension teaching program.

Evaluation

Each nominee will be evaluated on the quality of work as indicated by the documentary evidence submitted with the nomination relative to the following characteristics: effectiveness in teaching application of economic principles and tools of analysis appropriate to the problem and audience involved, ability to conceptualize new extension educational programs and application of new teaching concepts to existing programs, effectiveness in bringing about significant behavioral change and/or understanding of clientele, and contribution to improved extension teaching in agricultural economics as evidenced by participation in appropriate professional activities and organizations.

Submission

Nominations and supporting evidence must be submitted to the chairperson of the Distinguished Extension Program Awards Subcommittee.

Distinguished Policy Contribution

The distinguished policy contribution award recognizes an outstanding contribution to policy decisions or to the advancement of public understanding of major policy issues related to food, fiber, agriculture, and human welfare. Policy issues are interpreted in their broadest sense. They may relate to either a national or international situation. Their focus may be on production, marketing, or consumption. They include such things as price and income policy, environment and land-use issues, local government, rural poverty, and community development problems. The purpose of the award is to encourage interest in economic analysis of public policy issues that can provide timely and relevant information for more effective public policy and program decisions. The award is intended to focus attention on important efforts in research, education, or public service that facilitate the policy process and improve public performance and understanding. This award may be given annually.

Nomination

Individual or group efforts may be nominated. Nominations may be submitted by individual members, groups, or institutions. In addition, the Distinguished Policy Contribution Award Committee is encouraged to generate nominations to assure that all outstanding policy contributions are considered. Winners will be selected on the basis of the supportive material showing major contributions within the previous five years. Renominations are invited provided the supportive material is updated. Each nomination must be made by separate letter accompanied by documentary evidence supporting the nominee's contributions to the development and/or understanding of public policy. If the nomination is a group effort, all members of the group must be identified at the time of nomination. Eight copies of each entry should be submitted. Return of the material submitted is not customary but can be requested.

Evaluation

Entries must demonstrate significant contributions to the development and/or understanding of policy through research, extension, education, or public services activities. They will be evaluated on the quality of contribution to policy decisions or to the advancement of public understanding of major policy issues related to food, fiber, agriculture, and human welfare. Additionally, contributions will be evaluated based on the impacts they have had on the decision-making process. The effort must be a significant contribution to policy understanding as indicated by publication, program participation, or public response and awareness. The work should show evidence of demonstrated excellence in defining and articulating policy issues to the public and helping the public to understand and be aware of such issues.

Submission

All nominations and documentation should be sent to the chairperson of the Distinguished Policy Contribution Award Subcommittee.

Distinguished Undergraduate Teaching

The distinguished undergraduate teaching awards recognize and encourage meritorious performance in undergraduate teaching in agricultural economics. Two awards will be given: one for an individual with less than ten years of experience as an undergraduate teacher, and one for an individual with ten or more years of experience as an undergraduate teacher.

Nomination

Nominations may be submitted by any member(s) of AAEA. Winners will be selected based entirely on the supportive material submitted. Renominations are invited providing the supporting evidence is updated and resubmitted. Nominees must be actively engaged in teaching at a professional level during the current school year. Nominees must have demonstrated outstanding ability as an undergraduate teacher of agricultural economics. The format of the nomination material submitted should use as primary categories the five major criteria areas listed below. Include biographical data of the nominee—name, present position, education, and number of years of university-college teaching and experience in the profession. Supporting evidence must be limited to three pages for each of the five primary categories of the nomination. No more than three letters of reference from peers and students for each of the five primary categories should be included. Adjunct material may be included as an appendage to the nomination package if desired; for example, summaries of student class evaluations for courses taught. Eight copies of each nomination package are required.

Evaluation

Five major areas will be considered in evaluating nominations with relative weights as follows. (*a*) Quality of teaching (45%)—ability to motivate and stimulate student to learn; innovation for presentation and evaluation measurements; and mastery of subject, use, and application to business conditions. (*b*) Academic advising, counseling, and extracurricular activities of students (20%)—advising and counseling; and catalyzing extracurricular activities of students through department clubs or organizations, student council or senate, student publications, convocations, seminars, and community involvement. (*c*) Campus particupation in instructional, course, and curricular improvement efforts (15%)—department, college, and university-wide. (*d*) Professional improvement in teaching for benefit of self and peers (15%)—published textbooks, manuals, bulletins; research papers related to improved teaching; and participation in professional meetings and committees related to improved teaching and student activities. (*e*) Department/college/university teaching awards (5%)—student association/alumni awards.

Submission

Nominations and supporting evidence must be sent to the chairperson of the Distinguished Undergraduate Teaching Awards Subcommittee.

Professional Publications

Four major awards are given to encourage excellence in publications in all areas of agricultural economics. These are: Quality of Research Discovery, Quality of Communication, Publication of Enduring Quality, and Outstanding Article in the *AJAE.*

Quality of Research Discovery

There are no requirements regarding the number of authors or professional experience. Nominations may be submitted by individuals, departments, or agencies. Nine copies of each publication should be submitted, unless expense for the individual is excessive. Return of the publications is not customary but may be requested. Nominations should be submitted for only one award in either the quality of research discovery or the quality of communication category.

Nomination. A maximum of two awards are given. Entries must specify that the nomination is to be judged for the quality of research discovery. Entries must have been published in the previous calendar year.

Evaluation. The research must be a significant contribution to the field of knowledge in agricultural economics. The work should demonstrate excellence in research methodology and may deal with conceptualization of researchable problems as well as empirical verification.

Submission. Entries should be forwarded to the chairperson of the Quality of Research Discovery Awards Subcommittee.

Quality of Communication

The rules pertaining to the award for quality of research discovery also apply to this award for quality of communication.

Nomination. A maximum of two awards will be given. Entries must specify that the entry is to be judged for its quality of communication. Entries must have been published in the previous calendar year.

Evaluation. Entries must demonstrate superior communication of concepts or knowledge in any subject matter area or professional specialization (i.e., research, teaching, or extension) in agricultural economics to a specified audience. If dealing with transmission of research findings, the publication need not contain the author's original research but should improve communication within the profession as well as between it and other professions.

Submission. Entries should be forwarded to the chairperson of the Quality of Communication Awards Subcommittee.

Publication of Enduring Quality

Nomination. One award is offered for a publication having publication date during the fifteen-year period ending eleven years prior to the award year. Eligible entries are articles in the *AJAE* (during part of the period considered, the *AJAE* was known as the *Journal of Farm Economics*), regardless of whether the authors are AAEA members, and also other publications by authors, one of whom was a member of the AAEA at the time of publication. Entries must be submitted by departments or other administrative units, colleagues, or the authors themselves. Publications receiving an award in any other category in previous years are eligible for this award.

Evaluation. Entries are judged on the basis of the enduring quality of their contribution to the profession.

Submission. Entries should be forwarded to the chairperson of the Publication of Enduring Quality Subcommittee.

Outstanding Article in American Journal of Agricultural Economics

The editor and editorial council of the *Journal,* with the editor as chairman, will choose the outstanding article in the previous volume of the *Journal.*

Outstanding Master's Thesis

The outstanding master's thesis awards have as their objective development of professional excellence by individuals writing master's theses in agricultural, natural resource, or rural economics. Three awards are given. A cash supplement of $250 accompanies each award.

Nomination. Nominations may be made from any department in which students write master's theses in the areas of agricultural, natural resource, or rural economics. Any entry must be submitted by the head or chairperson of the department where the degree is earned. A department may submit one nomination for each fifteen master's theses or fraction thereof presented to a graduate school faculty in the previous calendar year. In determining the number of eligible theses, departments should limit consideration to theses in the areas of agricultural, natural resource, or rural economics.

Nominations should include thesis or other comparable documentation. Selection will be made from documentation approved in final form by the student's advisory committee. A thesis will be eligible for competition in the calendar year following the one in which the thesis was accepted by the graduate school or division. A published thesis may be entered in both the published research and master's thesis classes but is eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible. Three copies of a thesis (or comparable document) must be sent to the subcommittee chairperson. All copies are returned after they have been read by the judges.

Evaluation. Copies of evaluation criteria may be obtained from the subcommittee chairperson.

Submission. All nominations and documentation should be sent to the chairperson of the Master's Thesis Awards Subcommittee.

Outstanding Doctoral Thesis

The outstanding doctoral thesis awards are given in recognition of development of professional excellence by persons writing doctoral dissertations in agricultural, natural resource, or rural economics. Three awards are given. A cash supplement of $250 accompanies each award.

Nomination. An entry must be submitted by the head or chairperson of the department where the thesis or comparable document was presented in partial fulfillment of requirements for the Ph.D. degree. A department may submit one nomination for each twelve doctoral theses or fraction thereof presented in agricultural, natural resource, or rural economics to a graduate school faculty in the previous calendar year. In determining the number of eligible nominations, departments should limit consideration to theses in the areas of agricultural, natural resource, or rural economics.

Selection will be made from documentation approved in final form by the student's advisory committee. A thesis will be eligible for competition in the calendar year following the one in which the thesis was accepted by the graduate school or division. A published thesis may be entered in both the published research and thesis categories but is eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible. Three copies of a thesis must be sent to the subcommittee chairperson. All copies are returned after they have been read by the judges.

Evaluation. Copies of evaluation criteria may be obtained from the subcommittee chairperson.

Submission. All nomination and documentation should be sent to the chairperson of the Doctoral Thesis Awards Subcommittee.

Institutional Members—1981

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The Influence of Psychic Costs on Rural-Urban Migration

Brady J. Deaton, Larry C. Morgan, and Kurt R. Anschel

Psychic costs reflect differences in interregional utility, an important determinant of population among regions. Following Sjaastad's definition of psychic costs, the consumer surplus foregone by Appalachian migrants in two urban areas was measured as the difference between current urban income and an acceptable income level in eastern Kentucky. Psychic costs varied significantly with the size of the city of destination; migrants' demographic characteristics; and their satisfaction with jobs, city services, and interpersonal relationships in the city. Mobility which reduces psychic costs contributes to social well-being but will not be measured in national economic accounts.

Key words: Appalachia, costs of migration, migration, psychic costs, return migration, rural-urban migration, social adjustment, worker mobility.

The conceptual base for viewing migration as an investment in human capital was provided in Schultz' seminal article in 1961. Sjaastad's further development of the topic analyzed the rate of return on migration investments, recognizing that earnings differentials between regions can be expected even after sustained periods of migration. These differentials, Sjaastad emphasized, reflect, in part, the existence of "psychic" costs or lost consumer surplus rather than resource costs associated with migration. Yet, neither Sjaastad nor other subsequent work gives adequate attention to the topic.

Psychic costs signal utility differentials among geographic regions. These may induce migration, which results in a more socially optimal pattern of resource allocation than that induced by adjustments in market-determined wage rates. In his Nobel lecture, Schultz (1979) states, "The value of additional human capital depends on the additional well-being that human beings derive from it" (p. 13). Thus, a more complete understanding of migrants' perceptions of and responses to interregional utility differentials will provide both theoretical and practical insights into the geographic allocation of human resources, changing life quality, and the decision-making process affecting human mobility. These are important for an effective rural development policy (Hildreth and Schaller, Tweeten).

A strong preference for residing in rural communities is revealed in recent population and job movement from urban to rural areas. Psychic differentials favoring rural regions may be reflected in slower gross rates of outmigration from rural areas and in the current net migration from urban to rural communities. Simultaneously, the recognition by industrial leaders that relatively lower wages in rural areas are as acceptable as somewhat higher urban wages for equivalent jobs helps explain the rapid growth in rural manufacturing employment described by Lonsdale and Seyler.

This paper identifies and analyzes determinants of psychic costs and draws relevant implications for rural development policy. The analysis is based on measures of psychic costs and urban satisfaction for a pooled sample of eastern Kentucky migrants located in Cincinnati, Ohio, and Lexington, Kentucky.

Evolution of the Psychic Concept

Maddox warned that the psychic costs of migration were probably quite significant and could not be ignored by researchers and policy

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makers. Subsequent empirical research substantiated his suspicion that psychic costs are more important than monetary costs (Deaton, Morgan). His warning was largely ignored, however, to the detriment of intellectual inquiry and practical public policy. Most migration research has followed a more simplistic route with limited policy relevance. Earlier analysis of psychic components of the migration decision would have aided policy makers to anticipate the population reversal of urban to rural labor flows.

Sjaastad defined psychic costs as a consumer surplus equal to the maximum dollar income that could be taken from the individual before he/she would decide to migrate in order to improve his/her economic position. Weidemann and Sanders adopted this definition in their studies of return migrants in eastern Kentucky. Sanders found that an additional income increment of $4,000 per year (in 1968 dollars) would be required to induce former migrants to return to the city. Weidemann found that age, emotional adjustment, and income were significant determinants of psychic costs. Weidemann used the Bell Adjustment Inventory to measure emotional adjustment. Because of the small number of observations used in the regression, his results must be interpreted with caution.

Rohrlich directed our concern to the social opportunity cost of the psychic effect, implying that society will lose if a psychic factor keeps the migrant away from higher earnings in the city. This argument is sound only if dollars comprehensively measure social utility, a proposition few economists would support. More consistent with this paper is Hoch's argument that spatial wage differentials are essentially compensatory payments to offset the disutility of large population centers, after accounting for occupational selectivity and disequilibrium of wage adjustment.

Morgan and Deaton studied the income difference necessary to induce out-migration from three low income counties of eastern Tennessee. They found that willingness to migrate was positively associated with current earnings, level of education, and employment as craftsmen and operatives. These differences corresponded to similar distinctions between migrants and return migrants reported by Deaton and Anschel, especially regarding income, education, and age. Regression analysis in the Morgan-Deaton study supported their hypothesis of direct relationships between the psychic costs of migrating and age, marital status, family size, and family income. Contrary to their hypothesis, more educated people with jobs were less likely to move.

A Monetary Measure of Psychic Differentials

A field survey of 396 randomly selected eastern Kentucky migrants in Cincinnati, Ohio, and Lexington, Kentucky, provided the data for this study. Of these, 161 families had lived in Lexington for at least one and no longer than five years. The remaining 235 families had lived in the Hamilton County portion of the Cincinnati SMSA for at least one year and no longer than sixteen years. These time periods were determined by the restrictions imposed by the use of the census questions which determined the residential status of migrants.

During the interview each migrant was asked, "How much would you have to earn per month in eastern Kentucky in order for you to move back?" The response was adjusted to an annual basis to reflect the minimum acceptable annual income to return to eastern Kentucky. The psychic cost measure was then constructed by subtracting the present minimum acceptable income at the point of origin (eastern Kentucky) from the present total family earned (nonasset) income in the city.[1] The resulting income differential is the amount the migrant would either sacrifice or require in annual income in order to return to eastern Kentucky. All dollar figures reported in this paper were adjusted to 1970 price levels.

Attitudinal Traits Hypothesized to Influence Psychic Costs

The rural Appalachian-to-urban migrant experiences a unique shift in cultures, interpersonal relationships, and job orientation that may be highly disconcerting. The migrant-to-be is reared in a personal, familial, rural community. The decision to move often entails an abrupt shift from a community of family and friends to an impersonal, urbanized world, with a factory job for which the migrant is often ill-prepared. Overcoming this psychological rift may be a major task.

This study hypothesized that the most important of these psychological adjustments could be placed into three categories reflecting relative satisfaction toward (*a*) job (*JOBSCORE*), (*b*) friends and acquaintances in the urban community (*INTSCORE*), and (*c*) the public and private services and facilities of the city (*SERSCORE*) (Holmes, Kavanagh and Lowin, Weissenberg and Gruenfeld, Armstrong, Mukherjee).

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[1] The assumption was made that any transfer payments and asset earnings would continue to accrue to the family irrespective of geographic location.

Batteries of questions were constructed for each of these attitudes to elicit responses according to one of six degrees of agreement: (*a*) agree strongly, (*b*) agree, (*c*) agree slightly, (*d*) disagree slightly, (*e*) disagree, or (*f*) disagree strongly (adapted from Roen and Burnes). The values were correspondingly scored 1 to 6 to reflect successive degrees of relative dissatisfaction. Therefore, the lower the score the more satisfied was the respondent. A series of reliability tests were made on each battery of scale items. Any item that reduced the reliability of the index was deleted. Subsequently, an index for each attitude was constructed by calculating the simple mean for each respective battery of "valid" scale items. Validity in this context refers to a positive contribution to the reliability index.

The major hypothesis of the research is that the migrant's psychological satisfaction is inversely related to the amount of income they are willing to give up to return home. That is, a positive association is expected between the constructed indices (relative dissatisfaction) and the measure of psychic costs. Other independent variables included in the analysis and their hypothesized relationships are specified below.

(*a*) Family earned income in 1971 (*FAMINC*). Families with higher income levels were expected to be more satisfied with their current status and thus have a relatively lower psychic cost. However, since the magnitude of the calculated psychic cost is dependent upon the level of current family income, the hypothesis cannot be tested directly in this framework. The income variable serves primarily as a control variable facilitating the interpretation of other independent variables, especially *JOBSCORE, INTSCORE,* and *SERSCORE.*

(*b*) Migrant's occupation by grouped census categories was represented by one of five separate dummy variables reflecting professional and managerial (*PROF*), sales and clerical (*SAL*), craftsman and operatives (*CRFT*), and laborers (*LAB*).[2] Service workers was the normalized category. Higher status jobs were expected to be inversely related to psychic costs.

(*c*) Migrant's years of education (*EDUC*). Education is supposedly a force for socialization. Therefore, more educated individuals are expected to be more adaptive and, thereby, experience lower psychic costs.

(*d*) Migrant's sex (*FEMALE* = 1). Available literature suggests that females may have closer ties to their families and support systems in eastern Kentucky resulting in greater psychic costs in the city. A contrary notion, however, is that higher quality housing, health facilities, and city services will tend to reduce their psychic costs relative to males. Therefore, no relationship was hypothesized.

(*e*) Current property ownership in eastern Kentucky (*PROPEK* = 1). This variable measures the existence of a wealth linkage to the area of origin and, perhaps, a psychological propensity toward the region. Also, it may reflect future plans to return. A positive relationship was hypothesized.

(*f*) Migrant's current city residence (*CITY* = 1 for Lexington or 0 for Cincinnati). The smaller, home-state city of Lexington was expected to be associated with lower psychic costs.

(*g*) Distance migrated (*DIST*). Measured in miles, this variable is a classic proxy for relative orientation to the city. A positive relationship was hypothesized; i.e., migrants who come from nearer the city should experience lower psychic costs.

(*h*) Migrant's rural-urban origin in eastern Kentucky (*URBAN* = 1). It was hypothesized that migrants who lived in urban areas of eastern Kentucky, defined as towns with population 2,500 or above, will be more adaptable to urban life and will have relatively lower psychic costs.

(*i*) Years of residence in the city (*YRSRES*). Because the measure of several of the above factors probably will vary with length of residence in the city, the length of residence in years will correct for the distortion on the other measures. Social adjustment over time should be measured by the satisfaction indices.

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[2] The sixteen major census classifications were regrouped into six variables. Variable specification and respective census categories are as follows: *PROF*—(*a*) professional, technical, and kindred workers, (*b*) managers and administrators; *SAL*—(*c*) sales, (*d*) clerical and kindred; *CRFT*—(*e*) craftsmen and kindred, (*f*) operatives, except transport, (*g*) transport equipment operatives; *LAB*—(*h*) laborers, except farm, (*i*) farmers and farm managers, (*j*) farm laborers and farm foremen; *SERV*—(*k*) cleaning service workers, (*l*) food service workers, (*m*) health service workers, (*n*) personal service workers, (*o*) protective service workers, (*p*) private household workers.

The *SERV* variable was set equal to zero and all other variables set equal to one. Thus, the regression analysis tests whether migrants in any of the occupational categories had psychic costs different from the *SERV* category.

(*j*) Home ownership in the city of current residence (*OWNHOM* = 1). The purchase of a house in the city is likely to represent a more permanent tenure for the migrant and more successful adjustment to urban life. Hence, an inverse relationship was hypothesized.

(*k*) Family size (*FAMSIZ*). A positive relationship was hypothesized since living costs and potential adjustment problems are likely to be more severe as family size increases.

(*l*) Migrant's age at the time of migration (*AGE*). Migrants who enter the city at a younger age usually are more flexible and have not established a rigid pattern of social relationships and life style. Therefore, their adjustment to the city is more rapid and more complete. A positive relationship was hypothesized.

(*m*) Years of residence in other cities (*YRSRES*). Time spent in previous years in other cities should ease the socialization in the city of current residence. Hence, an inverse relationship was expected.

(*n*) Migrant's weeks of unemployment during the previous year (*UNEMP*). Unemployment leads to disenchantment with the city and lowers self-esteem. Thus, a positive association with psychic costs was expected.

(*o*) Migrant's participation in formal job training (*JOBTRN* = 1). Previous job training should ease transition into the city. An inverse relationship was expected.

(*p*) Migrant's military training (*MILTR* = 1). The travel and exposure provided by military service also should serve as a socialization process. Hence, migrants with previous military service are expected to experience less psychic cost.

Stepwise regression was used to develop the model with the lowest standard error of estimate. Table 1 presents the mean, standard deviation, and regression results for the variables in the "best-fit" model.

Results of the Analysis

The regression model explained 47% of the variation in the psychic income differential. The positive mean value for the dependent variable, psychic cost, suggests that the average migrant would give up $1,777 to return to eastern Kentucky. That is, earnings $1,777 below the current urban family earnings of $9,409, or $7,632, would apparently be an acceptable family income in eastern Kentucky. This level of psychic costs ($1,777) compares with direct cash outlays and foregone earnings incurred as moving costs from eastern Kentucky which averaged less than $100 for each sample (Deaton, Morgan). Also, psychic costs are a measure of a continuing utility differential. Other moving costs are incurred only at the time of moving and can be quickly recaptured via the higher earnings received in the city (Deaton, Maddox, Morgan, Sjaastad). The coefficient of the *FAMINC* variable suggests that $.74 of each additional dollar of income would be sacrificed to return to eastern Kentucky. However, the marginal value of $.26 plus the uncertainty of jobs and earnings in eastern Kentucky serves to keep them where they are.

The average worker in eastern Kentucky in 1971 earned $7,069 (Morgan, p. 165), only $563 below the earnings level designated as "acceptable" by this sample of urban migrants. Cost-of-living differentials as perceived by each individual are included in the measure of "acceptable" income. Since no adjustments were made for cost of living differences between eastern Kentucky and the cities, higher living costs in the city for a similar bundle of consumer goods would inflate the measure of psychic costs. There is little evidence to gauge the importance of this factor. However, preferences for alternative service mixes along with cost-of-living differentials between Lexington and Cincinnati are partially captured in the *CITY* variable, which was statistically significant at the .05 level. The regression coefficient of −2,086 for *CITY* indicates that, other factors held constant, migrants living in Lexington would have to be subsidized to return to eastern Kentucky. Consistent with Hoch's findings, these results suggest that disamenities increase with city size. On the basis of this data, Lexington is clearly a preferable destination for eastern Kentucky migrants.

This psychic cost measure reveals utility differentials between the rural origin and the urban destination. In a social welfare sense, migrants in this sample were equally satisfied by either their current income in the city or by residing in eastern Kentucky with $1,777 less

Table 1. Regression Model for Migrant Income Differential Needed to Return to Eastern Kentucky

Variable	Mean	Deviation	Coefficient	Regression Standard Error	F-Value
Psychic cost	1,776.64	5,135.09			
Constant			−6,240		
FAMINC	9,409.05	3,912.50	0.74	0.07	123.20[a]
INTSCORE	3.82	.94	1,205.73	313.76	10.66[a]
PROF	.18	.39	−2,357.38	722.00	12.62[a]
EDUC	11.65	3.01	− 169.41	99.72	2.89
FEMALE	.13	.33	3,001.34	784.35	14.64[a]
SAL	.13	.34	−1,862.81	770.71	5.84[b]
PROPEK	.10	.30	1,445.37	793.57	3.32
CITY	.44	.50	−2,085.53	837.23	6.21[b]
DIST	141.15	62.29	− 11.18	5.84	3.66
URBAN	.29	.46	−1,090.72	552.75	3.89[c]
YRSRES	5.95	3.83	− 105.20	72.07	2.13
SERSCORE	2.95	.70	532.71	419.81	1.61
OWNHOM	.38	.49	− 599.38	533.13	1.26
FAMSIZ	3.27	1.39	200.24	185.96	1.16

$\bar{R}^2 = 0.47$; $S_{\hat{y}} = 3742.82$: Regression $F = 17.52$: $N = 263$

[a] $F_{.01} = 6.64$.
[b] $F_{.025} = 5.02$.
[c] $F_{.05} = 3.84$.

earnings. This value increases significantly if only the Cincinnati sample is considered as a separate analysis revealed. The 235 Cincinnati residents in the sample would accept average rural earnings $3,138 below their current levels in order to be equally content.

Cincinnati migrants had an average family income of $10,203. Giving up $3,138 on average would place them essentially at parity with the average wage earner in eastern Kentucky. However, this does not suggest that the migrants will immediately return home. The wage level in eastern Kentucky is determined by specific skills, such as mining and heavy machine operations. This may not characterize the skills of migrants in Cincinnati. The comparable "appropriate" wage potential in eastern Kentucky for these workers may be substantially less. In addition, follow-up questions revealed that the Cincinnati migrants generally thought that jobs were simply either unavailable or insecure in eastern Kentucky. Hence, a comparison of general wage rates with psychic cost is not an adequate basis for predicting migratory responses.

The analysis reveals that each unit change in *INTSCORE* results in a $1,206 change in psychic costs. Interpersonal relationships seem to be more important in contributing to satisfaction with urban life than the other two attitudinal measures. However, *INTSCORE* and *SERSCORE* were intercorrelated at the $r = .61$ level, which could result in a loss of efficiency and possible bias in measuring the relative importance of these variables. Among the satisfaction indices, all other intercorrelations were below .25.

With other variables held constant, female household heads would sacrifice over $3,000 in income compared to male household heads to return to eastern Kentucky. The magnitude of this coefficient was surprising. Obviously, sex differences are important, though it is unclear whether they are due to different perceptions of the city, the area of origin, and/or other factors. This would be a fruitful area for further research.[3]

Two occupational categories were significant determinants of psychic costs. The results indicate that professionals (*PROF*) and sales workers (*SAL*) would have to be subsidized in the amounts of $2,357 and $1,863, respectively, as compared to service workers, to return to their home region. Different income levels, the perceived differential opportunities and occupational mix between regions, and the sociodemographic selectivity of these occupations interact to produce these results.

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[3] A reviewer suggested that the strong desire of female, single-parent households to be near friends and relatives (familiar social surroundings) for emotional support and assistance in child rearing should have led to the hypothesis of a strong positive relationship consistent with our findings. We concur with the plausibility of this suggestion and believe that it deserves future research attention.

The variable *URBAN* denoted migrants who had lived in towns of 2,500 or more in eastern Kentucky prior to moving. Our hypothesis was that small-town living was sufficiently different from a rural background so that subsequent adjustment to city life would be easier. The coefficient of 1,091 suggests that migrants from the relatively more urban environment of small towns in eastern Kentucky are less willing to return to eastern Kentucky. This is consistent with our hypothesis. The environmental contrast between either Cincinnati or Lexington and a small eastern Kentucky town appears to be less than between these metropolitan areas and the rural countryside and small communities.

Previous time lived in other cities outside eastern Kentucky (*OTHERCIT*), measured in months, did not influence psychic costs. As with the *URBAN* hypothesis, we expected such previous socialization to increase satisfaction with urban life. A major difference in the two variables may be that *URBAN* captures early childhood upbringing, whereas *OTHERCIT* reflects experiences after leaving eastern Kentucky. Measures of formal job training experience (*JOBTRN*) and military training (*MILTR*) which should ease transition did not enter the final equation. Other variables in table 1 with F-values above 1.0 but not significant at the .05 level of F ($F = 3.84$) had coefficients with signs consistent with our hypotheses.

The Relationship of Psychic Costs to Attitudinal Scores

A closer examination of the data revealed that migrants were more satisfied with their jobs (*JOBSCORE*) than with interpersonal relations (*INTSCORE*) or services in the city (*SERCORE*). The mean measure for *JOBSCORE* was 2.81 and the standard deviation was 0.68. The respective measures for *INTSCORE* were 3.82 and 0.94, and for *SERSCORE*, 2.95 and 0.70.

Migration literature is replete with evidence that social adjustments to the urban environment and psychological adjustment to the new urban work environment are the critical components of successful rural to urban migration. The cultural contrast between the rural Appalachian migrants and the urban dwellers of major northern manufacturing centers has provided grist for popular novels and generalized sociological observation. Hence, an attempt to clarify the major components of this cultural distinction is important. At the same time, migrant attitudes toward the cities of Lexington and Cincinnati can be examined in greater detail than that provided by the regression coefficient for *CITY*.

Job Satisfaction (JOBSCORE)

A battery of nine questions, each scaled to elicit one of six answers, was used to provide the index of relative job satisfaction. The survey questions were constructed and pretested after extensive consultation with psychologists and a review of literature on worker satisfaction and need fulfillment.[4]

A comparison of raw scores is presented in table 2 with t-tests. This provides an indication of differences between Cincinnati and Lexington for each question. The only statistically significant difference between cities among the responses were item (*c*) "My boss does not respect my work and ability." Cincinnati migrants were significantly more dissatisfied on this issue. Overall, however, these scores reflect general job satisfaction to a greater extent than either of the other two satisfaction indices. As the regression results revealed, *JOBSCORE* did not significantly influence psychic costs. There was less variation in the *JOBSCORE* responses than in the other indices.

Interpersonal Satisfaction (INTSCORE)

The significantly different attitude toward the boss' respect may indicate a general problem of interpersonal satisfaction. Table 3 reveals the scores by city for the eleven questions in the interpersonal satisfaction scale. Two observations are relevant. First, the scores to these questions are relatively—though not significantly—higher (i.e., approximately one standard deviation difference), indicating more dissatisfaction than those in the job satisfaction battery. Second, migrants in Cincinnati appear markedly less satisfied than those in Lexington, as reflected in the significantly higher scores for items (*d*), (*i*), (*j*), and (*k*). As the regression results revealed, a single point

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[4] In addition to referenced literature, extensive discussions were held with industrial psychologists, Joan Lee, Center for Developmental Change, University of Kentucky, and S. Harold Simonetti, IBM Corporation, Armonk, NY.

Table 2. Raw Scores and Tests of Significance (*t*-Tests) of Migrant Attitudes toward Urban Employment in Cincinnati and Lexington

	Lexington (N = 151)		Cincinnati (N = 215)		
Attitudinal Statement	Mean Raw Score[a]	Standard Deviation	Mean Raw Score[a]	Standard Deviation	*t*-values[b]
a. I am satisfied with my present job.	2.25	1.24	2.49	1.26	−0.71
b. My present job does not make the best use of my skills and abilities.	3.41	1.60	3.47	1.57	0.47
c. My boss does not respect my work and ability.	2.36	1.36	2.83	1.45	−2.89*
d. Most of my coworkers are good friends.	2.01	0.89	2.07	0.75	−0.40
e. For the kind of work I do, I do not get paid enough.	3.63	1.57	3.39	1.60	1.06
f. I have the kind of job that offers a secure future.	2.85	1.56	3.10	1.56	−0.62
g. A good thing about my job is that I am allowed to do my own work.	2.22	1.24	2.41	1.17	−1.31
h. The work here is safer than it is in eastern Kentucky.	3.34	1.60	3.37	1.46	−0.72
i. In general, I believe that working conditions here are better than they are in eastern Kentucky.	2.25	1.19	2.47	1.27	−1.48

[a] Raw scores are based on sample sizes of 151 and 215, respectively. All observations with unemployed migrants or missing scores were removed from the total samples of 161 and 235. Also, observations with missing values were omitted from the calculations of each response.

[b] *t*-values based on separate variance estimates. Starred figures are significantly different from zero at the .05 level.

change in *INTSCORE* contributed $1,206 to psychic cost, indicating a marked cultural difference between Lexington and Cincinnati. However, this interpersonal dissatisfaction does not seem to carry over to the work place.

Satisfaction with Urban Services and Facilities (SERSCORE)

Twelve attitudinal statements on schools, traffic, medical care, recreation, and housing constituted the *SERSCORE* measure (table 4). The raw scores indicate that the migrants were most satisfied with medical services in Lexington and are least satisfied with Lexington traffic. Cincinnati migrants were most satisfied (i.e., strongly disagreed) with item (*k*) which stated, "Young people have a better chance in life in eastern Kentucky because they can get a job more easily than they can here." The numbering system (1–6) was reversed for those items which stated a preference for eastern Kentucky conditions, so that low scores consistently reflect greater satisfaction with the city (e.g., statements *d*, e, and *k*). Cincinnati migrants were most dissatisfied with crowded housing and congestion (*c*) and city traffic (*f*). The responses to both items (*e*) and (*l*) reflected a general concern about relatively poor medical services in eastern Kentucky.

Earned Income, Foregone Psychic Income, and Occupations

Relationships among earned income, psychic costs, and occupations are of primary economic interest. They were analyzed by city by

Table 3. Raw Scores and Tests of Significance of Migrant Attitudes toward Urban Interpersonal Associations

	Lexington ($N = 151$)		Cincinnati ($N = 215$)		
Attitudinal Statement	Mean Raw Score[a]	Standard Deviation	Mean Raw Score[a]	Standard Deviation	t-values[b]
a. I am dissatisfied with my associations with other people here.	2.21	1.12	2.33	0.95	0.04
b. Here I have more of a chance to relax and enjoy myself than I did in eastern Kentucky.	3.72	1.67	4.04	1.62	−1.27
c. People in eastern Kentucky seem to understand me better than people here.	3.01	1.45	3.46	1.50	−1.92
d. My whole family is happier here than they were in eastern Kentucky.	2.77	1.42	3.53	1.60	−3.63*
e. People here take an interest in my problems.	3.36	1.41	3.70	1.45	−1.64
f. If I lived in eastern Kentucky I would have more close friends than I have here.	3.79	1.61	3.75	1.50	0.85
g. I have more friends to visit with here than I had in eastern Kentucky.	4.19	1.41	4.07	1.39	1.12
h. People seem more friendly and easygoing here than in eastern Kentucky.	4.49	1.21	4.59	1.12	−1.02
i. I feel more free to do what I want in eastern Kentucky than I do here.	3.07	1.52	3.68	1.51	−2.78*
j. It is important for a person to break away from his home community and live in a new place.	3.25	1.51	3.58	1.46	−3.12*
k. People here look down on anyone from eastern Kentucky.	2.80	1.32	3.28	1.52	−2.92*

[a] Raw scores are based on samples of 151 and 215, respectively. All observations with missing scores were excluded from the calculation of each response.

[b] t-values based on separate variance estimates. Starred figures are significantly different from zero at the .05 level.

grouping the respondents according to their relative satisfaction. Scores ranging from 1.0 to 3.0 were designated "satisfied"; between 3.0 and 4.0, "indifferent"; and 4.0 to 6.0, "dissatisfied." Table 5 provides a comparison between the frequency in each satisfaction category with the mean family earned, nonasset income, and the level of psychic cost displayed as foregone psychic income.

Positive values for psychic costs indicate dissatisfaction with aspects of city life. The higher the psychic cost, the more willing is the family to accept a lower income to return to eastern Kentucky. Therefore, by remaining in the city, the migrant is foregoing psychic income whenever a positive value occurs. Positive psychic costs can be conceptually viewed as foregone psychic income, or foregone consumer surplus in Sjaastad's terms.

This display of data is consistent with our earlier results. It reveals that most migrants were content with their jobs. No particular pattern emerged with regard to either the level of earned income or foregone psychic income. Such a clear pattern of job satisfaction was not expected in this study. It runs counter to the popular view that Appalachian workers have difficulty adjusting to urban employment. They seem relatively content with their jobs.

A far greater proportion of migrants fall into

Table 4. Raw Scores and Tests of Significance of Migrant Attitudes toward Urban Services

	Lexington (N = 151)		Cincinnati (N = 215)		
Attitudinal Statement	Mean Raw Score[a]	Standard Deviation	Mean Raw Score[a]	Standard Deviation	t-values[b]
a. It is easier to do shopping and carry out personal business here than it was in eastern Kentucky.	2.53	1.37	2.53	1.17	−0.23
b. I live in better housing here than I did in eastern Kentucky.	2.93	1.49	3.06	1.48	−0.05
c. Housing here is too crowded. There are too many people living close together.	3.95	1.50	4.51	1.20	−2.37*
d. Considering everything, people are better off living in eastern Kentucky than an area like this.	2.80	1.38	3.47	1.47	−3.18*
e. I feel safer living in eastern Kentucky where there are better medical services.	1.80	0.73	2.17	0.87	−3.89*
f. One of the worst things about living here is the traffic.	4.49	1.34	4.24	1.37	0.06
g. Considering everything: schools, jobs, friends, and family, this is a better place to raise a family than eastern Kentucky.	2.86	1.37	3.74	1.49	−3.37*
h. It is easier to get around here than it is in eastern Kentucky.	3.34	1.46	3.59	1.47	−0.67
i. The movies, parks, and public facilities here provide more opportunity for recreation than I had in eastern Kentucky.	2.19	1.13	2.87	1.37	−3.63*
j. Children here get a better education than they do in eastern Kentucky.	2.55	1.34	3.16	1.42	−3.41*
k. Young people have a better chance in life in eastern Kentucky because they can get a good job more easily than they can here.	1.99	0.77	2.01	0.62	−0.93
l. Medical services in eastern Kentucky are not as available as they are here.	2.15	1.18	2.49	1.13	−2.93*

[a] Raw scores are based on samples of 151 and 215, respectively. All observations with missing scores were excluded.
[b] t-values based on separate variance estimates. Starred figures are significantly different from zero at the .05 level.

the "indifferent" and "dissatisfied" categories with respect to interpersonal associations in the city. The modal group in Lexington is "indifferent" while the "dissatisfied" group is modal for Cincinnati. Lexington migrants are more or less evenly distributed on each side of indifferent, while the Cincinnati migrants are skewed toward dissatisfaction.

Descriptive data on these samples revealed that Lexington migrants were more highly educated, migrated at a younger age, and occupied higher status job categories. These factors likely contribute to a more pleasant and rapid socialization process in Lexington. Also, the cultural differences between Lexington, a "native state" city and Cincinnati, a northern

Table 5. Migrants' Levels of Revealed Satisfaction

	Lexington			Cincinnati		
Levels of Satisfaction	*N*	Earned Income	Foregone Psychic Income	*N*	Earned Income	Foregone Psychic Income
Job						
Satisfied	101	9,985	160	148	9,987	2,779
Indifferent	39	8,392	- 623	54	9,978	4,195
Dissatisfied	2	10,454	6,434	8	8,541	2,202
Interpersonal						
Satisfied	41	9,614	-2,525	51	9,677	624
Indifferent	71	9,599	- 80	70	10,370	3,748
Dissatisfied	37	8,574	1,603	88	9,585	3,855
Service & facility						
Satisfied	110	9,384	- 687	108	10,154	2,415
Indifferent	37	9,422	725	86	9,500	3,493
Dissatisfied	2	6,024	1,464	15	9,958	5,220

city, likely contribute to the greater alienation of Cincinnati migrants. This is consistent with a related study by Morgan and Deaton.

The psychic income levels are consistent with these hypotheses. Although earned income does not vary significantly by level of satisfaction, the psychic income shows a distinct pattern. The willingness to give up income varies directly with the level of dissatisfaction. The Lexington migrants who are either "satisfied" or "indifferent" would have to be subsidized to return to eastern Kentucky, but the "dissatisfied" group would give up an average of roughly $1,600.

The Cincinnati migrants in every category would give up income to return to their home region. "Satisfied" migrants would give up an average of only $624, but the seventy "indifferent" families would give up $3,748 and the "dissatisfied" group, $3,855, more than a third of the earned income for the latter two groups.

Satisfaction with city services and facilities followed a pattern similar to job satisfaction. Most migrants are content with service availability and quality in the city, with Lexington migrants more content than Cincinnati migrants. The fifteen families who were dissatisfied in Cincinnati indicated a willingness to forego, on the average, well over half their income to return to eastern Kentucky.

Conclusions

The psychic costs reported in this sample of rural-to-urban migrants reflect preferences for rural life and more familiar social surroundings. Income differentials suggest that migration, at least in some cases, is associated with negative private externalities and that interregional factor price differentials are inadequate measures of relative welfare. These findings are consistent with Hoch's hypothesis that the observed interregional wage differentials represent, in part, compensation for disutility associated with urban life and that disutility increases with city size. The smaller city of Lexington, Kentucky, was clearly preferred to the larger metropolitan area of Cincinnati, though each is close to the area of origin. A decade of change in both rural and urban areas may alter some of the measured perceptions reported in this study which used 1971 data. These measures are consistent with the urban-to-rural population movements experienced recently.

The satisfaction measures indicate that the quality of work in the city may be a less important deterrent to migration and successful social adjustments than the quality of the social and physical surroundings. Perhaps the social linkages between rural communities and nearby cities, regardless of size, are the most important determinants of psychic costs.

Interregional income differentials can be expected to persist indefinitely, as long as nonpecuniary externalities of economic activity play a major allocative role. Programs that assist migrants to adjust to urban environments may lower psychic costs and help eliminate the high personal and economic costs associated with "return" migration from urban back to rural areas of origin. The results of this study suggest that a significant proportion of migrant dissatisfaction can be explained by demographic measures. Development planning should be sensitive to psychic differentials associated with different population characteristics.

The frustrations of interpersonal interactions may be significantly reduced if migrants understand urban life better. For newcomers to the city, socialization programs can be offered through school systems, state employment services, and community organizations. In determining the optimal mix of urban and rural-oriented human resource development policies, the net social benefits of these programs should be compared with those of programs that induce firms to locate in rural areas.

Government investments have influenced the flow of migrants by altering income and employment opportunities in rural and urban areas. The urban to rural trends of industry and population may reflect the success of these policies. The results of this study imply that the determinants of psychic costs contribute to the same trends. Policy makers should consider the impacts of all these factors upon migration flows if desired population distribution is to be achieved and undesirable consequences avoided.

These results provide evidence that decentralizing industry may generate an increase in societal well-being that goes beyond improvements in rural wages. Job opportunities at acceptable real wages in rural communities provide opportunities for a significant number of return migrants from urban areas. Apparently, these return migrants avoid substantial psychic costs which will never enter an accounting stream but, nevertheless, contribute to personal utility. Few would doubt that all society is the beneficiary.

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Constraints on Oxen Cultivation in the Sahel

Christopher L. Delgado and John McIntire

Ox-powered cultivation is common in parts of the Sahel, yet most farmers in the region continue to cultivate manually. Insights from oxen farms in Mali are compared to nonadopters in Upper Volta. Ox-driven technology in the Sahel may be more labor shifting than labor saving. Linear programming models indicate a prohibitive opportunity cost of extra labor required for team maintenance and use on small, rainfed farms growing traditional millets and sorghums in Upper Volta. Farm simulations suggest that ox plowing increases cash crop acreage, but clearly profitable adoption requires companion innovations to boost labor productivity in peak periods.

Key words: animal traction, labor, linear programming, oxen, Sahel, technology adoption.

This paper attempts to clarify why farmers in some areas of tse-tse-free West Africa have rapidly adopted animal traction using oxen (ATO) in recent years, while most cultivators in the dry, savannah areas of the coastal states and the Sahelian nations (collectively the "Sahel") have not. The use of cattle as draft animals is viewed as a major change in the farming system because it involves major shifts in resource utilization and constraints. The major hypothesis is that ATO in isolation from companion innovations provides only marginal improvements in net returns to farm labor in much of the Sahel. Under these conditions, the benefits of the new power source can be wiped out by costs of new resource bottlenecks farmers face as they adopt the new technology. Evidence from a farm management survey of nonadopters in a dryland millet area of Upper Volta is contrasted with that from a survey of oxen users in a flooded rice/dryland millet area of Mali. A hypothetical model of farm resource allocation opportunities is constructed from the Voltaic data with added ATO options specified from the Malian research under assumptions favorable to ATO use. Maximum potential increases in farm income and the required resource reallocations stemming from adoption of ATO are then discussed.

Cattle Entrustment and ATO in the Sahel

Although many farmers in the Sahel own cattle, relatively few look after the animals themselves. Typically, cattle are entrusted to specialized herding groups such as the Fulani, who often live outside the villages of sedentary crop cultivators (Delgado 1979b). The herdsmen thereby gain milk, manure, goodwill from farmers who control the land, and occasional cash payments. Farmers reap the appreciation in the value of the livestock. Even in the absence of inflation, it is often profitable to hold on to older bullocks. In West Africa, the value per head may continue to increase past age eleven *ceteris paribus* (Herman), while the marginal entrustment cost for pasturing on the common range is relatively low. Mortality is also lower for older, proven, animals (Delgado 1979b).

Farmers who invest in cattle, in Upper Volta at least, are typically forced to choose between maintaining the animals themselves or year-round entrustment (Delgado 1979b). This is because herders wish to leave the populated zones on seasonal migration (transhumance) at least two months before the beginning of the rainy season, in search of pas-

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Delgado took major responsibility for writing and supplied the Upper Volta data generated under USAID contract AFR-C-1169 with the University of Michigan. McIntire provided the Malian data generated under USAID contract AFR-C-1235 with Stanford University.

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ture. Farmers, on the other hand, cannot easily maintain stock in the village area at this time. In fact, there would be little motivation for entrusting animals to the Fulani at all if owners wished to maintain cattle on the farm through both the hot, dry period and the agricultural growing season.

The choice of most Sahelian smallholders to entrust their cattle stymies attempts to introduce integrated crop-cattle farming, often regarded as an important element of agricultural progress. ATO, in particular, frequently has been advocated by agricultural advisors as the single most important technical innovation available to farmers in the region (Zerbo and Le Moigne, Johnston). The expected benefits of ox plowing hinge on increased timeliness of sowing (Le Moigne), better soil structure, water infiltration, rooting, and the maintenance of soil fertility with manure (Nicou and Poulain).

In light of projected benefits for ATO and the obvious success of these technologies in Asia, it is not surprising that the introduction of bullock-driven technology in the Sahel is widely advocated. Lichte estimates that there have been at least 125 agricultural development projects in Francophone West Africa since the 1930s that emphasize animal traction technology.[1]

Given the strong policy thrust in favor of ATO projects, it is puzzling to note the poor adoption and high abandonment rates observed in many projects throughout the region (Delgado 1979a). Average equipment densities per net sown hectare vary widely over the Sahel. Le Moigne estimates that in 1977 there was one plow for every 12 hectares in Mali but only one for every 190 hectares in Upper Volta. The figure for India in 1966 was one plow per 3.4 hectares (Government of India). Among the Sahelian countries, Mali had the highest density of plow oxen in 1975 at one per 11 hectares. However, the growth rate in numbers of plows used in Mali fell from 9% per annum in the 1960s to 2% per annum from 1973 to 1976 (Zerbo and Le Moigne).

A Hypothesis to Explain Nonadoption

Lack of profitability is a sufficient explanation of nonadoption of a new technology. The return to family labor is an appropriate profitability criterion from the farmer's viewpoint in Africa's labor constrained systems (de Wilde; Lele; Newman, Ouedraogo, Norman). Seasonal labor bottlenecks may be so tight in some areas that the most profitable cropping pattern is largely determined by the relative returns to labor in these peak periods (Norman, Pryor, Gibbs). The weeding of cereals in July and the November harvest are periods of particularly intense activity. As elsewhere in the Sahel, the lack of an elastic supply of hired seasonal labor in Upper Volta forces most small farmers to rely upon family and cooperative labor to overcome peak labor demands (Delgado 1979a).

The nature of ATO technology with respect to labor use is especially important in this context. Adoption of ATO could be unprofitable if it is more labor shifting than labor saving. This could occur if work requirements increased in periods when the opportunity cost of labor is relatively high, even if total labor use per hectare is diminished. It is even possible that total labor input per unit of output increases under some circumstances. Clearly profitable use of ATO requires that higher labor returns at certain times of the year more than compensate for net cash costs of adoption and lower returns to labor during other periods.

Various writers have observed that the ATO packages recommended in Africa often neglect the very real bottlenecks of weeding and harvesting (Lele, Von Rotenhan). Experiment station data for draft cultivation of sorghum in Upper Volta show a 17% decrease in seedbed preparation time compared to a 10% increase in weeding time per hectare and a doubling of the harvesting labor requirement relative to traditional manual cultivation (Dupont de Dinechin et al.). Citing Senegalese farm data, Le Moigne claims that the use of ox plowing adds twenty-four to thirty man-days per hectare to labor requirements for cotton and eighteen to twenty-four for millet. In the latter case, half the extra labor is required to cope with higher yields, while a third is needed for increased weeding. Weed growth per hectare is increased because crops must be grown in rows far enough apart to accommodate oxen. Furthermore, increased need for weeding and harvesting labor per hectare with ATO is aggravated by the extension of acreage that usually accompanies the new traction power source.

In principle, inclusion of an animal-drawn hoe in ATO packages should decrease weeding items. However, less than one-fifth of participants in twenty-seven ATO projects surveyed in the Sahel used weeding equipment, although it was part of the package in twenty of the projects reviewed (Sargent et al.). The reluctance of Sahel farmers to risk crops with ATO after they are knee-high has been widely noted (de Wilde; Delgado 1979a; Newman, Ouedraogo, Norman). This ubiquitous result suggests problems with the technology rather than problems with farmers' attitudes.

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[1] Personal communication, 1979.

In addition to labor requirements during the cropping season, use of ATO technology on small farms involves substantial increases in dry season labor to maintain animals formerly entrusted to migrating Fulani herdsmen. Obtaining water and pasture requires trips far afield at precisely the time oxen must be readied for maximum work effort. Farm labor tied up in an ATO unit may have a high opportunity cost in terms of off-farm work. This is especially true in Upper Volta and Mali where many young men spend the dry season in coastal countries as migrant workers or petty tradesmen.

The results of profitability studies in two very distinct Sahelian environments will be presented and compared to test the opportunity-cost-of-labor hypothesis. The first study involves a millet-sorghum-peanut area of Upper Volta. Here ATO adoption has been negligible despite many efforts to the contrary (Delgado 1979a). The second examines ATO in smallholder irrigated paddy farming in Mali. Here ATO has a long and successful history (McIntire 1980).

A Casual Comparison of Oxen Profitability

Delgado generated a complete set of input-output production data for forty-one farms randomly selected from two villages in the Tenkodogo district in southeast Upper Volta (1979a). The survey included labor allocations to all activities, derived from twice-weekly interviews repeated from April 1976 through May 1977. At the end of the survey, there were reportedly 750 plows in the district for roughly 370,000 people, despite efforts over twenty years to introduce ATO practices (Zerbo and Le Moigne). A companion survey of twenty Fulani households determined the major requirements for maintaining cattle in that area.

The main crops are millet, sorghum, peanuts, cowpeas, and bambara groundnuts on upland soils and swamp rice in lowland areas. Annual rainfall is typically between 900 and 950 millimeters per year. Hired labor is not generally available because job seekers tend to migrate to the coast.

In 1976, the average eight-person family farm surveyed consisted of 3.85 hectares of crops spread over seventeen widely scattered fields. Roughly four-fifths of the mean smallholding was devoted to crop combinations involving millet and sorghum. The average household owned one or two cattle and a half dozen small ruminants. Cattle were never kept on the farm but entrusted to nearby Fulani herdsmen.

A simple linear programming model was constructed, based on (*a*) observed fortnightly labor allocations to various cropping activities, (*b*) hypothetical livestock activities based on the herder survey, and (*c*) hypothetical crop activities using ATO. The latter incorporate percentage increases in crop yields, decreases in seedbed preparation time, and increases in weeding and harvesting labor requirements, all drawn from experiment station information. (See Delgado 1979a, for details.) The model assumed that farmers have sufficient resources either to purchase an oxen team for farm use or to entrust two head of cattle to the Fulani year-round, but not both. Entrusting two plow oxen to the Fulani only during the dry season was not considered. This is because the Fulani herds are typically 60 kilometers away from farming villages in search of pasture for two months after the start of the plowing season (Delgado 1979b).

The conclusion suggested by this rather simple approach was that farmers are better off investing livestock capital through entrustment to the Fulani for beef production rather than using it for plow oxen maintained on the farm. This holds even if the team can be sold for meat after several years, because the cost of ATO is essentially the opportunity cost of maintaining the team year-round. This cost is prohibitive because little labor is saved in weeding and harvesting and relatively low benefits occur for the traditional varieties of food grains.

In contrast with most of Upper Volta, ATO practices are widespread in arable Mali (Zerbo and Le Moigne). McIntire surveyed 152 randomly selected households in the Opération Riz area of Ségou from September 1977 to January 1978. Virtually every farm used ATO. Twenty-one households averaging eight inhabitants were interviewed more intensively to obtain farm management information.[2] The mean smallholding in the subsample was 5.1 hectares, four-fifths of it under irrigated rice. The remainder was planted to millet and peanuts on upland soils.

Linear programming was used to evaluate the profitability of ATO; plowing services could be rented in July for 10,000 Malian francs (FM) per hectare, the mean observed rate in Ségou in 1977.[3] Oxen ownership was not evaluated for the model, but ATO rental proved to be highly profitable in every case considered. The main benefits from ATO use stemmed from extension of holdings and substitution of rented oxen hours for hired manual labor hours during the July seedbed preparation bottleneck. Total labor input, including family labor, increased in the model as a result of the ATO option. Significantly, the overall profitability of ATO was contingent on the availability of a flexible source of hired labor later in the year. In both actual observation and model simulation, per hectare yield benefits from ATO were difficult to distinguish from effects of increased and more timely fertilizer use.

A comparison of survey results from Tenkodogo and Ségou suggests that two important factors contribute to greater ATO profitability in the latter. First, of course, is the difference in crops. High-yielding rice, like cotton and maize, requires extensive seedbed preparation. Millet, on the other hand, requires little or no tillage on the sandy upland soils of Tenkodogo. ATO in the Sahel typically is used for seedbed preparation, and it simply may not be practical unless rice, cotton, or maize are widely grown. Second, hired labor availability during the rainy season also distinguishes Ségou from Tenkodogo. Young Tenkodogo men desiring wage work tend to migrate to Ivory Coast for seasonal or year-round jobs at higher wages than at home. This suggests that intensification technology is not viable when seasonal labor is severely constrained.

Accordingly, investigating how resource constraints determine ATO profitability narrows to testing the importance of (*a*) the potential for expansion of acreage into high-yielding crops that require extensive seedbed preparation labor and (*b*) the flexibility of labor supply at times of peak labor demand. The framework is the original model for the nonadopting area, Tenkodogo. More flexibility will be added by providing options to hire labor and grow selected crops not usually planted in Tenkodogo. The range of oxen-drawn implements, such as carts, and livestock opportunities also will be expanded. The goal is to identify important missing elements in the Tenkodogo environment affecting ATO profitability. The additional flexibility in the model, although unrealistic, helps ensure that unprofitability for ATO is not simply a result of an overly rigid model.

A Hypothetical Farm Model of ATO in the Sahel

A composite linear programming farm model was constructed for a Tenkodogo-like environment in order to simulate major trade-offs in the farming system, given resource availability, costs, and the Tenkodogo price environment of 1977. Then hypothetical livestock and ATO activities were added, based on the Ségou model. This is better than using experiment station data because a significantly greater degree of flexibility in the number of options available is added. To further increase the scope for analysis, some hypothetical cotton-growing enterprises also were devised based on Malian farm management norms for an area just south of Ségou (République du Mali).

Rice, peanut, millet, and cotton enterprises (observed in Ségou) may not be real options for Tenkodogo farmers. In fact, it is unlikely that irrigated rice or cotton will ever be an important part of the Tenkodogo farming system. However, it is permissible for present purposes to add these extra options, provided that significant real opportunities also are included. This is because the objective is to illustrate some major constraints to ATO profitability, not to promote it. The goal here is simply to observe trade-offs among production strategies as input supplies and technological options are varied. This permits a clear view of the opportunity costs when a radically different set of (ATO) enterprises is added to a well-defined farming system.

The new model contains 115 activities and 64 constraints. The core is a dense matrix of 29 crop and livestock enterprises, estimated from the Tenkodogo survey data. Labor supplies and requirements are specified on a fortnightly basis. Four types of land are available for use in quantities consistent with average holdings observed in Tenkodogo. The additional activities estimated from the Ségou data are added to the core in groups depending upon the simulation desired.[4] They represent a series of ATO crop enterprises, some manual crop enterprises not observed in Tenkodogo, and a series of oxen rental or hiring options. Options to hire labor at Ségou rates are also specified, although not observed in Tenkodogo. In the simplest form, the model is an improved version of the Tenkodogo farm model used by Delgado (1979a). In the full form, the model includes more flexibility than any farmer in the Sahelian savannah is likely to possess. This gives ATO more than a fair chance at hypothetical profitability in Tenkodogo. Different runs can be made in include or exclude cotton or irrigated rice. Manipulation of land constraints permits modeling the effects of lower population density and greater access to irrigated or more fertile soils.

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[2] Recall, census, and informant techniques were used; time limitations prevented a detailed cost-route survey of the type Delgado did for Tenkodogo.

[3] 10,000 Malian Francs (FM) = 5,000 West African Francs (CFA) = approximately US$22.75 in 1976.

Given the importance of labor constraints, it is instructive to note the differential effect of ox plowing on labor use for millet (the food staple) and peanuts (the major cash crop in Tenkodogo). Table 1 shows that ox-driven technologies in Ségou use less labor than manual practices in Tenkodogo. In an absolute sense, therefore, animal traction appears to be labor-saving per hectare of land, a more optimistic assumption than the cited literature suggests. Even so, a differential pattern between crops emerges regarding returns to work. For food grains, the returns to total labor inputs are higher with traditional manual intercropping. For peanuts, however, the reverse is true. To the extent that the system is labor constrained at weeding and harvesting times, ox plowing is more likely to be useful the greater the proportion of holdings devoted to the cash crop as opposed to the food crop.

Results: The Profitability of ATO on Three Farm Types

Results for small, rainfed farms without the option of hired labor are shown in table 2. The models simulate conditions in Tenkodogo with the added ATO options of Ségou for rainfed crops. The results show that ATO increases farm income if farmers can contract for ox-plowing services at Ségou rates. Even so, the optimal strategy selected by the small, rainfed farm models is to use oxen on half the land, generally maintaining intensive manual inter-

Table 1. Observed Differences in Yields and Labor Inputs per Hectare between Technologies in Tenkodogo and Ségou

Crop	Food Grains (Millet)				Cash Crops (Peanuts)			
Technology		Manual Tenkodogo	Ox-driven Segou	Change (%)		Manual Tenkodogo	Ox-driven Segou	Change (%)
Yield in kg./ha.	Millet	280	500		Peanuts	346	600	
	Cowpeas	672			B. g'nuts[b]	180		
Net revenue in CFAF/ha.[a]		23,500	16,400	−30		19,500	26,400	+35
Seed bed preparation labor		42 man/days	20	−52		25	22	+12
Weeding and thinning labor		30	25	−17		47	22	−53
Harvest labor		29	34	+17		48	30	−38
Total labor		101	89	−12		120	74	−38
Return in CFA per man/day of total labor input		233	184	−21		163	357	+119
Return in CFA per weeding man/day		783	656	−16		415	1,200	+189
Return in CFA per harvest man/day		1,022	482	−53		406	880	+117

Note: The Tenkodogo figures measure averages in 1976 for manual intercropping three weeks apart without rows (Delgado 1979a). The Ségou figures represent averages in 1977 for cultivation in line (McIntire 1980). Both sets of figures refer to in-village land not fertilized with organic matter from the compound.

[a] At 1976 (220 CFAF = US$1.00) Tenkodogo prices and cash costs.

[b] Bambara groundnuts.

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[4] The main specification problems lay in harmonizing the assumptions concerning labor requirements, labor availabilities, timing of inputs, prices, costs, soils, and yields as specified in the two models. With labor coefficients and availabilities, the guiding principle was to adjust the unit scale of one model vis-à-vis the other without changing the distribution and relative size of requirements within a given activity.

Table 2. Optimal Solutions for Models of Small Rainfed Farms without Hired Labor

	Units	Actual Average (N = 41) Tenkodogo	Maximum for Average Farm[a]	Model A (Manual Crops + on-farm Cattle)[b]	Model B (Ox Cultivation + Optional Ownership)[c]	(Model C (Model B + Mandatory Ownership)	Model D (Model C + Team Can Be Rented Out)
Maximum attainable able farm income	1,000s CFA	125	138	163	187	135	183
Total cropped area[d]	ha.	3.83	3.32	3.32	4.40	4.19	3.38
Area cropped in millet and sorghum	ha.	3.27	2.93	2.93	1.53[e]	1.48[e]	1.42[e]
Area cropped in peanuts and cotton	ha.	0.27	0	0.15	2.72	2.29	1.63
Total of oxen team/days used	team days (1 day = 4h)	0	0	0	19	18	12
Level of oxen team ownership chosen	pairs of oxen	0	0	0	0	1 team	1 team
Percentage of holding on which oxen are used	%	0	0	0	51	42	36

[a] The optimal strategy at average prices and yields differs from the average actual pattern principally through the smaller area devoted to cereals (millet, sorghum) and cassava (not shown). This can be interpreted as farmers' risk-management strategy to ensure adequate food supply.

[b] Includes stall feeding of cattle with project-supplied concentrates as practiced in Ségou. It shows that mixed farming may be profitable if cattle feeding is limited to the slack period before the end of the dry season. This precludes animal draft cultivation, which begins at this time.

[c] Ownership includes two oxen, a plow, hoe, cart, and associated labor requirements and maintenance costs; if oxen are not kept, then ATO may still be used by hiring at 5,000 CFA/hectare for plowing and 500 CFA/4 hours for transportation.

[d] Also includes areas cropped in paddy, maize, cassava, and vegetables.

[e] Food production falls very little relative to Model A despite a decrease in acreage. This is due to significantly higher yields from using manure and a shift to higher-yielding food crops.

cropping of food grains to assure food supply. This is consistent with the finding by Norman that traditional manual mixed cropping of food crops yields better returns per man hour in the bottleneck season (Norman, Pryor, Gibbs). It is also consistent with observations in Eastern Upper Volta, where an average of 59% of the fields in a 1978 sample of ATO farms were plowed with oxen, the remainder being worked by hand.[5] Given the importance of millet and sorghum on the small, rainfed farms modeled, the potential increase in farm income from the introduction of ATO in the absence of hired labor is an estimated 15% (comparing Models A and B, table 2).

In the case of team ownership, the profitability constraint is even more serious. Maximum attainable farm income actually decreases by 17% on small, dryland farms if farmers maintain their own team and are not permitted to rent it out (compare A and C, table 2). On the other hand, attainable income increases 12% relative to the pure manual case if the farmer can rent out his team when not using it (compare A to D, table 2). However, if such a rental market exists, farmers should contract for their needs (compare B and D, table 2). In sum, the recurring costs of maintenance are sufficiently great relative to benefits on the 4-hectare dryland holdings typical of Tenkodogo that individual team ownership is dubious at best.

On small, rainfed farms without hired workers, the opportunity cost of labor resources required to maintain a team is the most important constraint to ATO profitability. The major bottlenecks in the system are millet harvest labor in November and, to a much lesser extent, weeding labor in July. Animal traction per se can reduce the first problem if carts are used; the shadow price of November labor is cut by one-half with contract carting in Model B. However, the opportunity cost of labor in ATO models at weeding time (late June and July) increases by a factor of two to three as extra demands on a fixed supply of labor arise from expanded acreage and team maintenance. The predominance of the latter as a cost factor may be seen in the 28% decline in optimal revenue moving from Model B, where plowing services are contracted, to Model C, in which the team and equipment are maintained year-round.

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[5] Personal communication from David Wilcock, 1980.

Furthermore, a serious, new, labor bottleneck appears in May in Model C (table 2). This is the end of the dry season, when considerable effort is required to feed and water oxen and spread the dung. These extra burdens compete with the traditional tasks of field clearance. The opportunity cost of maintaining a team without hired labor (Model C) is sufficiently high relative to the pure manual case to offset the extra returns from a 20% increase in total acreage, including the substitution of 2 hectares of cash crops for 1.5 hectares of food grains.

What happens if the resource constraints of the Tenkodogo situation are gradually relaxed? An infinitely elastic supply of hired labor is assumed to exist. Results are shown in table 3. Maximum attainable income in the pure manual case (Model E) is approximately the same as if hired labor were not available but ATO units could be rented. (Models B and D, table 2). This suggests substitutability between hired labor and hired ATO units, but does not resolve the question of ATO unit ownership on small, rainfed farms.

The effect of adding ATO to models with labor-hiring options (F, G, and H, table 3) is to double the acreage of cash crops in the optimal solutions and to intensify food production on a smaller area of higher-yielding, manured grains. However, maximum attainable farm income under these conditions increases only 9% relative to the pure manual case with hired labor. This suggests, *ceteris paribus,* that the profitability of ATO with hired labor is closely linked to the ratio between the value of cash crops and the cost of hired labor per hectare.

The models provide insight into the role of ATO as an acreage expander. In Models I and J, rainfed-land constraints are virtually eliminated. In the most profitable case, the optimal strategy is to double acreage to 9.7 hectares, with 70% under cash crops, and contract for all plowing services (Model J). However, maximum attainable farm income is still only 25% above the pure manual case. This occurs because of the high cost of the extra man-days

Table 3. Optimal Solutions for Farm Models with Hired Labor

	Units	Model E (Small, Rainfed Farm, ATO Not Possible)	Model F (Small Farm, ATO Ownership or Hiring Optional)[a]	Model G (Small Farm, ATO Owernship Mandatory)	Model H (Small Farm, ATO Ownership Mandatory, But Can be Rented Out)	Model I (Large Farm, ATO Ownership Mandatory)	Model J (Large Farm, ATO Ownership or Hiring Optional)	Model K (Large Ségou Irrigated Land Endowment)[b]
Maximum attainable farm income	CFA 1,000s	184	199	144	200	173	228	488
Total cropped area	ha.	4.29	5.01	4.63	5.00	7.34	9.71	8.11
Area cropped in millet and sorghum	ha.	2.24	1.26	1.23	1.26	2.03	2.49	1.24
Area cropped in peanuts and cotton	ha.	1.56	3.36	3.01	3.35	4.93	6.82	2.07
Area cropped in paddy	ha.	.04	.04	.04	.04	.04	.04	4.45
Level of oxen team ownership chosen[a]	pair of oxen	0	0	1	1	1	0	1
Total oxen days used	team-days	0	15	26	17	55	71	64
Total man-days of hired labor	man-days	99	79	74	69	192	259	251
Percentage of holding farmed with oxen	%	0	34	52	25	66	64	88

Note: Hired labor evaluated at 400 CFA/man-day from May to December and 250 CFA otherwise. Large farms are endowed with 8 hectares of good cotton land and unlimited access to cleared bush land.

[a] See note c, table 2.

[b] Includes 3.75 hectares of nearby rainfed land, 4.7 hectares of irrigated paddy land, and unlimited access to bush land.

required to weed and harvest the larger and more labor-intensive crop (160 more paid days in J than in E). The main effect of larger farm size is to shift the labor problem from the opportunity cost of team maintenance to the new labor requirements for expanded crop cultivation.

ATO becomes really profitable when major changes in seed technology and irrigated land resources are available. Model K represents the hypothetical case where the Tenkodogo household is suddenly endowed with the land and seed technology available to a household of the same size in the Ségou rice area. Next to increased profitability, the most significant change is a much higher degree of monocropping. More than half of the optimal holding is under paddy. The main labor demand occurs at planting time in July and August, and ATO helps alleviate this bottleneck.

Summary and Conclusions

The main barrier to adoption of oxen cultivation in the Sahel is the prohibitive opportunity cost of extra labor associated with the technology. The implicit overhead cost of labor to maintain the ox team is the major problem on the 4-hectare farms typical of the Tenkodogo area of Upper Volta as well as in many of the millet-sorghum growing areas elsewhere in the Sahel. On one hand, per head labor requirements for oxen maintenance are high because of small average herd size and lack of dry season forage and surface water. On the other hand, returns of ATO are small on labor-constrained millet-sorghum farms. Output of these grains per peak-season labor input may be even higher with traditional manual intercropping than with draft cultivation. Assuming either that farmers in these areas wish to be self-sufficient in food grains or that they wish to maximize profits, there simply are not enough resources on these small farms to use ATO at a profits level consistent with rapid adoption.

The opportunity-cost-of-labor argument is slightly different where large tracts of nearby land suitable for cash crops and an elastic supply of hired labor are available. In this case, draft cultivation permits a substantial increase in cash crops. Ox-plowing facilitates planting of peanuts and cotton at roughly the same time as the first weeding of cereals, a task that otherwise would be difficult. However, the expansion of cash crop acreage is accompanied by new labor demands for thinning, spraying, weeding, and harvesting. The profitability of oxen cultivation under these conditions depends upon the ratio between the extra wage bill and returns from expanded production.

Farming systems research aimed at extending oxen-drawn technology must analyze companion innovations which reduce the time required for weeding and harvesting. Light, animal-drawn weeders, easily repaired carts, herbicides, and small-scale mechanical threshers offer promise. Using hired labor alone to cope with new labor bottlenecks from extended acreage is not likely to be profitable in the Sahel unless technological change boosts crop yields above traditional levels.

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Optimal Grain Carryovers in Open Economies: A Graphical Analysis

Keith C. Knapp

Optimal storage, trade, and borrowing policies for grain are analyzed graphically using dynamic programming. World prices and domestic harvests are assumed to be stochastic. Optimal carryovers are generally increasing in supply and decreasing in world prices, while net imports are decreasing in both supply and world prices. Optimal levels of carryovers and net imports are influenced by the opportunity to borrow and save foreign exchange. It is shown that grain reserves and foreign exchange borrowing/saving are alternative inventory systems which both complement and substitute for one another.

Key words: dynamic programming, foreign exchange, grain, stockpiling, trade.

The principles of optimal grain stockpiling in a closed economy were first established by Gustafson. If supply is defined as current harvests plus carryovers from the previous year, then optimal carryovers are zero for supplies below a certain critical level and increase at a rate between zero and +1.0 as supply rises above that critical level. These properties are also postulated by Samuelson with extensions and additional discussion found in Gardner.

The purpose of this paper is to develop the theory of optimal carryovers in open economies subject to stochastic fluctuation in domestic harvests and world grain prices. Empirical studies of optimal carryovers in trading countries include Johnson and Sumner for developing countries (see also Johnson), and Burt, Koo, and Dudley; Gardner; and Alaouze, Sturgess, and Watson for the United States and Australia. The model in this paper is applicable to either importing or exporting countries and generalizes existing models by allowing storage and trade decisions to be controlled independently and by assuming that foreign exchange can be transferred between periods. A secondary purpose is to demonstrate that useful insights into optimal grain reserves can be obtained by a simple graphical analysis based on economic principles.

The formal model is set out in the first section of the paper. The next three sections consider trade; storage and trade; and storage, trade, and foreign exchange borrowing/saving. Applications of the analysis and concluding remarks are in the final two sections.

The Model

The following notation is used throughout: c_t is grain consumption in period t; m_t, grain imports in period t (exports if negative); x_t, grain carryovers from period t to period $t + 1$; y_t, amount of foreign exchange borrowed in period t (savings if negative); h_t, grain harvests occurring at the end of period t; p_t, price of grain in world markets; s_t, domestic supply of grain; and a_t, foreign exchange debts (additional reserves if negative).

The domestic supply of grain available for use in period t equals the sum of harvests and carryovers from the previous period net of storage losses:

$$s_t = h_{t-1} + \beta x_{t-1}, \tag{1}$$

where β denotes the fraction of carryovers remaining after storage losses. Carryovers are constrained to be non-negative but less than the storage capacity, X:

$$0 \le x_t \le X, \tag{2}$$

and grain can be imported (m_t positive) or exported (m_t negative). The total supply of grain available for use in period t is domestic supply plus net imports, and this is divided between consumption and carryovers into the next period:

$$c_t + x_t = s_t + m_t. \tag{3}$$

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Domestic harvests and the price of grain in world markets are stochastic, and their joint distribution is assumed to be given.

Foreign exchange may be borrowed to pay for current imports or saved for future use. The amount of foreign exchange to be repaid in any period is just the amount borrowed in the previous period plus interest at the rate r:

$$a_t = (1 + r)\, y_{t-1}. \tag{4}$$

(If foreign exchange is saved, then $-a_t$ is the additional foreign exchange available for use in period t). Although foreign exchange is borrowed or saved for intervals of a single period, loans can be renegotiated so that, in effect, foreign exchange borrowed in period t can be paid off in any future period with interest (likewise for savings). In the final period, the additional constraint

$$y_T = 0 \tag{5}$$

is imposed.

Net benefits in each period are given by

$$NB_t = W(c_t) - \gamma x_t - C(p_t{}^b m_t + a_t - y_t), \tag{6}$$

where $W(c_t)$ are benefits from grain consumption (assumed here to be the area under the domestic demand curve for grain) and γ denotes per unit variable storage costs. The foreign exchange used by the grain sector in period t (or, more exactly, the foreign exchange not available for imports of other commodities) is $p_t{}^b m_t + a_t - y_t$, where $p_t{}^b$ is the world price plus transport costs for imports or minus transport costs for exports. The opportunity costs of this foreign exchange to the economy are given by the function C, which is assumed to be convex and differentiable with $C(O) = 0$ and $C'(O) = 1$. (If the foreign exchange used is negative because grain is exported or foreign exchange was saved in previous periods, then $-C$ represents the benefits from using this foreign exchange elsewhere in the economy.)

In each period the country must decide how much grain to import or export, how much to store for future use, and the level of foreign exchange borrowing, if any. These decisions are functions of domestic supply, world prices, and any foreign exchange obligations from previous periods:

$$x_t = f_t(s_t, p_t, a_t),$$
$$m_t = g_t(s_t, p_t, a_t),$$
$$y_t = q_t(s_t, p_t, a_t),$$

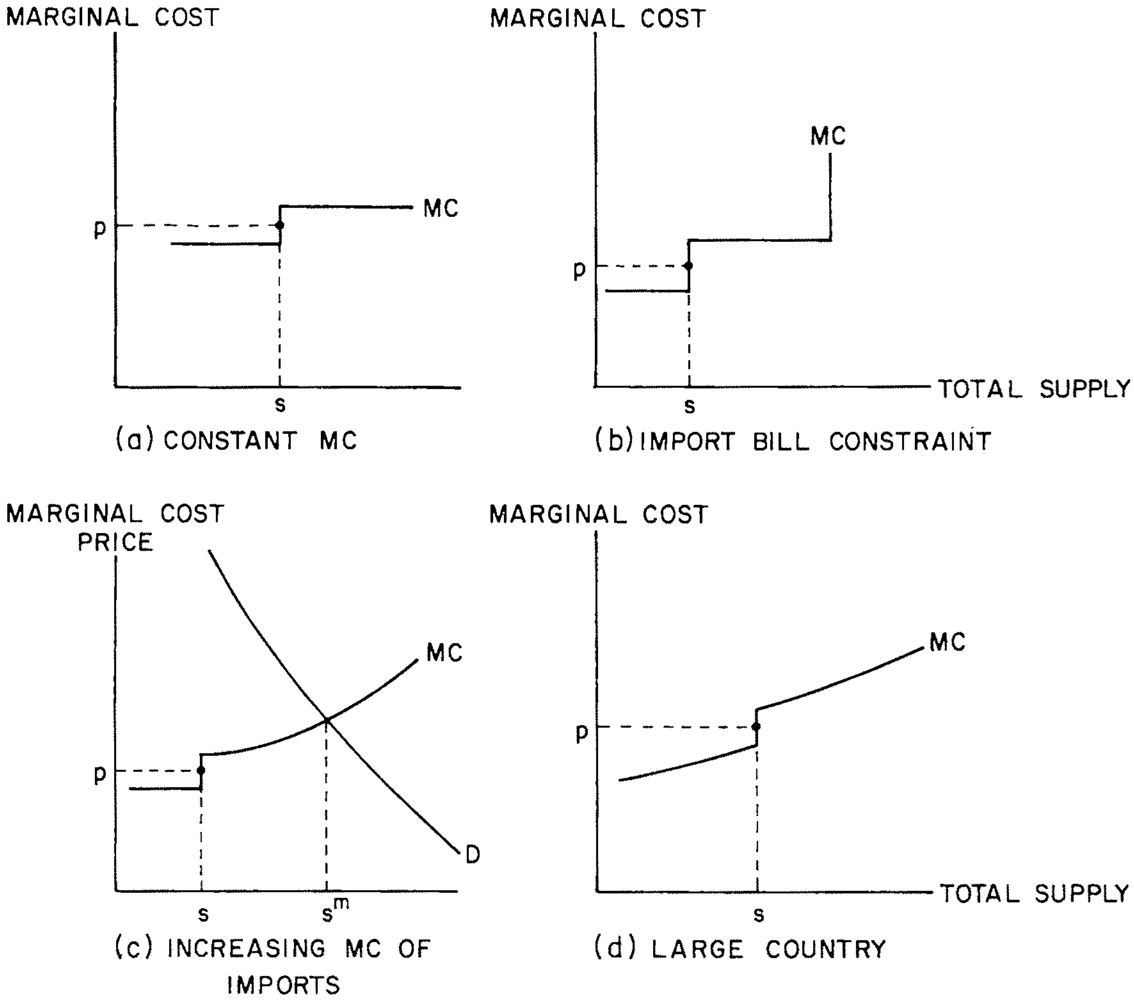
where the functions f_t, g_t, and q_t are termed the storage, trade, and borrowing rules, respectively. The optimization problem is to choose a sequence of rules which maximizes the expected value of discounted net benefits subject to equations (1), (3), and (4). In addition, the storage rules must satisfy (2), the borrowing rule in the last period must satisfy (5), and the initial levels of domestic supply, world prices, and foreign exchange obligations are given.

Trade

Countries vary considerably with respect to their grain-trading characteristics. They may be classified as normally importing, exporting or self-sufficient depending on their trade in grain in years of average domestic harvest levels and world prices. Some countries are small enough to be price takers in world markets, while others may have significant effects on international grain prices. Countries may also be considered as foreign exchange constrained depending on the ease with which additional foreign exchange can be obtained for grain imports in years of poor domestic harvests or high world prices.

These different situations can be analyzed using a marginal cost function for total grain supplies, where total grain supplies equal domestic supply plus imports or minus exports. For a given world price and domestic supply level, the marginal cost function shows the opportunity cost to the economy of obtaining additional units of supply, whether by increasing imports or reducing exports.

The shape of the marginal cost functions depends on the size of the country relative to world markets and whether or not the country is perceived as having "foreign exchange constraints." Some of the possibilities are illustrated in figure 1. Panel (a) represents the case of a small country with no foreign exchange constraints. Marginal costs and benefits of imports and exports are constant at their respective border prices. These are the usual assumptions of partial equilibrium analysis. Panel (b) illustrates the case of a constraint on foreign exchange expenditures. Marginal benefits of exports are constant for all levels of exports, while marginal import costs are constant up to a maximum import level, after which they are infinite. This assumption was used by Reutlinger and others. Panel (c) represents a more gradual version of the same



(a) CONSTANT MC

(b) IMPORT BILL CONSTRAINT

(c) INCREASING MC OF IMPORTS

(d) LARGE COUNTRY

Figure 1. Marginal cost functions for total grain supply

idea. The marginal costs of imports are approximately the border price for low levels of imports but begin to increase as import levels increase.

The intuitive idea underlying the *MC* curves in panels (b) and (c) is that additional grain imports put increasing pressure on scarce foreign exchange supplies. Additional foreign exchange is generated either by reducing imports of other goods and services or increasing exports. If domestic consumption of other goods and services is reduced enough, prices will increase, implying increased marginal opportunity costs for grain imports. The *MC* curves in panels (b) and (c) are also consistent with empirical evidence showing that in many developing countries production shortfalls are only partially compensated by increased imports (Abbott). (If marginal import costs are constant, then consumption is constant for small variations in domestic supply; whereas the assumptions here imply that domestic consumption does respond to production shortfalls.)

Panel (d) indicates the case of a country which is large relative to the world grain market. Additional exports depress the world price, while additional imports increase the world price. These effects result in declining marginal benefits from exports and increasing marginal costs of imports.

The determination of optimal imports and exports in the absence of carryovers and foreign exchange borrowing/saving is illustrated in panel (c) of figure 1. Total supply is determined by the intersection of *MC* and the domestic demand for grain (*D*). Optimal imports and exports are just the difference between total and domestic supply. Grain is imported if the intersection occurs to the right of domestic supply and exported if it occurs to the left of domestic supply. In the situation illustrated optimal grain imports equal $s^m - s$.

While each of the various cases discussed above can be handled in the framework of this paper, the analysis is essentially the same for each.[1] In the sections that follow, the case of a small, normally importing country with restricted foreign exchange availability will be illustrated. The marginal cost function is assumed to be as in panel (c) of figure 1, implying that the cost of trade function C, introduced in the previous section, is strictly convex when m_t is large enough.

Storage

The optimization problem formulated in the first section is solved using dynamic programming. For each period, typically, optimal value functions are defined, which give the expected value of discounted net benefits under optimal operation in future periods as a function of the state variables in that period. The algorithm consists of calculating the optimal value function for the last period, then the next to last period, and so on, until optimal value functions have been calculated for all periods. The optimal decisions are just the solutions to the maximization problems defining the optimal value functions.

The problem may also be solved using the first derivative of the optimal value function (Gustafson). This procedure is illustrated here for the case of no borrowing/saving of foreign exchange using a simple graphical analysis. Like indifference curve analysis in consumer theory or isoquant analysis in production theory, this graphical approach yields considerable insight into the optimal carryover and trade decisions without resorting to extensive numerical computations or complicated formal derivations.

For convenience, it is assumed that there are only two possible harvest levels, each occurring with a probability of 0.5, two possible world prices which also occur with probability of 0.5, and the distributions of domestic harvests and world prices are independent.

The situation in the last period is depicted in figure 2 under the assumption that no grain has been carried over from the previous period. D^c is the domestic demand curve for grain consumption and the MC^i schedules, $i = 1, \ldots, 4$, are the marginal cost of total grain supplies. Given the world price and domestic harvest levels, import/export levels are determined by the intersection of the MC^i curves and D^c, as described previously. No grain is stored since this is the final period.

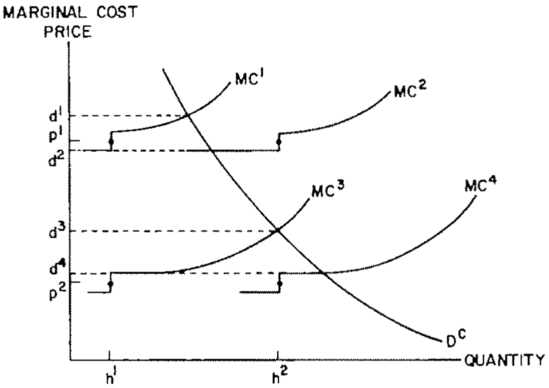


Figure 2. *MC* functions in the final period when carryovers from the previous period are zero

In period $T - 1$ we will need to know the benefits of storing alternate amounts of grain. To that end, we can calculate the marginal value of additional domestic supplies in period T. The marginal value of an additional unit is just the domestic price, and this depends on the realized values of the random variables. (Note that the domestic price can differ from the world price by virtue of the assumptions about MC.) If harvests are h^1 and the world price is p^1, then the marginal value is d^1. Similarly, the marginal value is d^2, d^3, and d^4 under the other three possibilities. Therefore, the expected marginal value of the first additional unit of domestic supply in period T is $\sum_{i=1}^{4} d^i/4$.

The expected marginal value of the second additional unit of domestic supply is calculated in the same way as the first, the only difference being that the MC^i curves are shifted to the right by one unit (since domestic supply now equals harvests plus one additional unit) and, hence, the expected marginal value of the second unit is less than that of the first. Continuing in this manner, we construct a downward-sloping expected marginal value function for additional grain supplies in T. Multiplying this by $\beta/(1 + r)$ and subtracting γ gives the expected marginal value of carryovers in period $T-1$ net of storage costs. This curve is referred to here as the carryover demand curve and is depicted as D^x in figure 3. Note that D^x is truncated at the capacity level X.[2]

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[1] A finite storage capacity must be assumed for the case illustrated in panel (a); otherwise the optimization problem defined in the first section may be unbounded.

The optimal consumption, trade, and storage decisions in period $T-1$ are illustrated in figure 3 for the case of domestic supply s. The carryover demand curve and consumption demand curves have been summed horizontally to get the total demand curve D. The intersection of MC and D determines the total supply and the domestic price in period $T-1$. Optimal imports/exports are the difference between total and domestic supply, while optimal carryovers and consumption are determined by the domestic price from the carryover and consumption demand schedules, respectively. In figure 3, if the world price is p, then optimal imports are m^*, optimal carryovers are x^*, and optimal consumption is c^*. The optimality of this procedure is easily checked. For example, in the situation illustrated the marginal value of consumption equals the expected marginal benefits of carryovers net of storage costs, and both equal the marginal cost of imports. Optimal carryovers will be zero only when the domestic price is greater than d^0 and will equal capacity when the domestic price is less than d^x.

The next step is to determine the marginal benefits of carryovers and the optimal decisions in period $T-2$. This is done as before except that D is used instead of D^c to calculate the marginal value of additional supplies in $T-1$ and, hence, the carryover demand schedule in $T-2$. The procedure is repeated until all periods have been considered. It can be seen that in every period a downward-sloping carryover demand schedule will be obtained and the optimal decisions will be determined as in figure 3.

It is now possible to show how optimal carryovers depend on the world price and domestic supply. First, suppose that in figure 3 the domestic supply is fixed at s. For low world prices optimal carryovers are positive. As the world price increases, MC shifts up and optimal carryovers decrease. For high world prices optimal carryovers are zero.

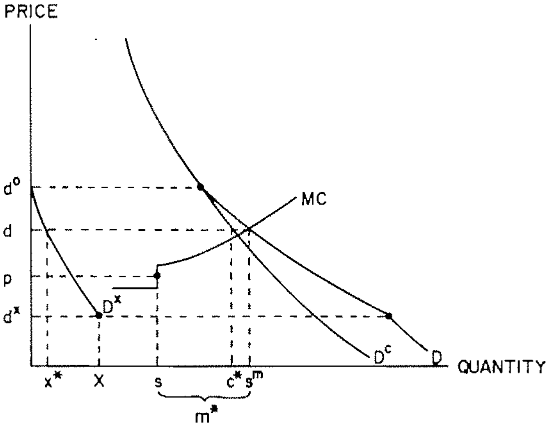

Figure 3. Optimal trade and storage decisions

Now, suppose that the world price is fixed at p. For low levels of domestic supply optimal carryovers may be zero. As domestic supply increases, MC shifts to the right and optimal carryovers increase. Furthermore, the rate of increase is between zero and one as in the closed economy case. To see this, suppose that supply increases by one unit, thus shifting MC to the right by one unit. Because D is downward sloping and MC is upward sloping, it can be seen that total supply s^m will increase by less than one unit. On the other hand, the domestic price decreases, so optimal consumption also increases. Thus the increase in optimal carryovers must be less than one unit. (Optimal imports can be characterized in a similar fashion.)

Foreign Exchange Borrowing/Saving

Operation of grain reserves when foreign exchange can be transferred between periods is considered in this section. The problem is of interest because at first it may seem that foreign exchange borrowing/saving is a preferable inventory system to grain reserves. In good years (low world prices and large domestic supplies) foreign exchange can be saved for future use. Interest is earned and transaction costs are minimal in contrast to grain carryovers which are subject to handling costs, losses in storage, and investment in expensive storage facilities. In addition, foreign exchange may be borrowed in poor years (high world price and low domestic supplies), which reduces the need for grain carryovers. The analysis of this section shows that this is only part of the story. In years of low prices it may pay to borrow foreign exchange, increase imports, and put the additional grain into storage. Thus, these two alternative inventory systems are complements as well as substitutes for one another.

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[2] The carryover demand schedule may have a horizontal section if D intersects each of the MC schedules in a horizontal section. This may also occur for some of the other marginal cost schedules in figure 1. In the situation illustrated in panel (a) of figure 1, a "bang-bang" solution will result. Grain carryovers are either zero or at capacity.

It will be possible to illustrate this relationship once the following two propositions have been established:

(*a*) Borrowing foreign exchange shifts the carryover demand schedule up, while saving foreign exchange has the opposite effect.

(*b*) If the marginal cost of foreign exchange is defined as

$$C'(p_t m_t + a_t - y_t),$$

then foreign exchange is optimally borrowed (or saved) so as to equalize the marginal cost of foreign exchange in the current period with the expected marginal cost of foreign exchange in the following period.

The first proposition is shown graphically. (To simplify the analysis, it is assumed that there are only two time periods and that transport costs are zero, implying that grain can be imported or exported at the world price p_t.) In figure 4, D^c is again consumption demand, (p^1, h^1) and (p^2, h^2) are two possible combinations of world price and domestic harvests occurring in the second period, and x denotes carryovers from the first period. Suppose, now, that B dollars in foreign exchange are borrowed in the first period and must be repaid in the final period with interest. When the world price is p^i, this is equivalent to reducing the domestic supply in the second period by $(1 + r)B/p^i$ units.[3] Since the MC^i curves are then shifted to the left, the expected domestic equilibrium price increases and therefore the marginal benefits of carryovers from the previous period increase. This is true for any carryover level x, and so the carryover demand curve for the first period shifts up. An analogous argument shows that saving foreign exchange in the first period for use in the second period will shift the carryover demand schedule down.

The second proposition is shown using the Kuhn-Tucker conditions. In the second period the maximization problem to be solved is to find the import levels which maximize

$$W(s_2 + m_2) - C(p_2 m_2 + a_2).$$

Optimal imports are a function of s_2, p_2, and a_2, and this function is denoted g_2. Optimal imports must satisfy the condition

$$\text{(7)}\quad W'[s_2 + g_2(s_2, p_2, a_2)] = p_2 C'[p_2 g_2(s_2, p_2, a_2) + a_2],$$

which says that the marginal benefits of consumption must equal the marginal cost of imports. Expected net benefits in the second period are a function of x_1 and y_1. This function is denoted H_2 and is defined by

$$\begin{aligned} H_2(x_1, y_1) = \underset{h_1, p_2}{E} \Big(W\{h_1 + \beta x_1 &+ g_2[h_1 + \beta x_1, p_2, (1 + r)y_1]\} \\ &- C\{p_2 g_2 [h_1 + \beta x_1, p_2, (1 + r)\, y_1] + (1 + r)y_1\}\Big). \end{aligned}$$

In the first period the problem is to maximize $H_1(x_1, m_1, y_1) = W(s_1 + m_1 - x_1) - \gamma x_1 - C(p_1 m_1 - y_1) + \dfrac{1}{1 + r} H_2(x_1, y_1)$, subject to $X \geq x_1 \geq 0$ and the initial conditions s_1 and p_1. Taking the partial derivative of H_1 with respect to y_1 and using (7) yields the following condition to be satisfied by optimal carryovers, imports/exports, and foreign exchange borrowing/saving in the first period:

$$C'(p_1 m^*_1 - y^*_1) = \underset{h_1, p_2}{E} \Big(C'\{p_2 g_2[h_1 + \beta x^*_1, p_2, (1 + r)\, y^*_1] + (1 + r)y^*_1\}\Big),$$

where it has been assumed that g_2 is differentiable. This shows that the optimal level of foreign exchange borrowing must equalize the marginal cost of foreign exchange in the first

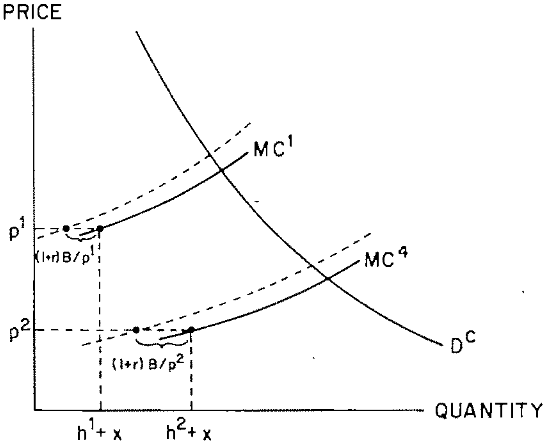

Figure 4. Shifts in the second period *MC* functions when B dollars of foreign exchange are borrowed in the first period

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[3] One way to see this is as follows. The country owes $B(1 + r)$ in foreign exchange. It pays this debt off by exporting $B(1 + r)/p$ units of domestic grain supply. The marginal costs of total supplies are then calculated from the new domestic supply level.

period with the expected marginal cost of foreign exchange in the second period, which is proposition (*b*).

The effects of foreign exchange borrowing/saving on grain carryovers can now be illustrated. In figure 5, D is the horizontal sum of consumption and carryover demand in the first period under the assumption that no foreign exchange has been borrowed or saved. The import price, p, and domestic supply, s, are chosen so that carryovers are positive. If the marginal cost of foreign exchange is less than the expected marginal cost of foreign exchange in the second period, then foreign exchange will be saved. This shifts MC leftward to MC' and D down to D', resulting in fewer carryovers compared to the case of no foreign exchange borrowing/saving. If the marginal cost of foreign exchange is greater than the expected marginal cost in period 2, then foreign exchange will be borrowed. This shifts MC rightward to MC'' and D upward to D'', so optimal carryovers are increased.[4]

Applications

The preceding sections have analyzed the relation between optimal grain carryovers and world grain prices, domestic harvest levels, and foreign exchange reserves. Under certain conditions, private sector stockholding will be optimal (Gustafson). In this case these results provide a theory about the behavior of the private storage industry and can be used to show how different government policies may affect aggregate carryover levels. Alternatively, the results characterize optimal storage rules for public grain reserves in the absence of private stockholding, assuming that the objective function (6) is the appropriate one.

The graphical approach may be used for sensitivity analysis. For example, suppose that per unit storage costs increase. Then it can be seen that the carryover demand schedule shifts down so optimal carryovers decrease for a given domestic supply/world price combination. The same result occurs if the interest rate or losses in storage increase. As another example, suppose that world prices are serially correlated in such a way that a low world price in the current period increases the probability of low world prices in the next period. This could occur, for instance, because of grain inventories held in other countries. If a low price does occur in the current period, then the increased probability of low world prices in the next period implies that the carryover demand curve shifts down. Therefore optimal carryovers at low world prices will be smaller with serial correlation than without.

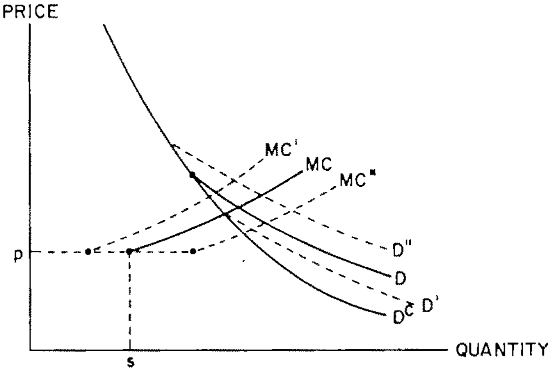

Figure 5. Effects of foreign exchange borrowing/saving on grain carryovers in the first period

The approach may also be useful in formulating policies to meet other stabilization objectives. This can be illustrated by reference to the following problem considered by Reutlinger and Konandreas, Huddleston, and Ramangkura, among others. Suppose that in figure 6, D is total demand, and the country decides to insure that consumption never falls below some critical level C^{min}. The problem is to determine the policies to accomplish this.

Maintaining grain consumption levels above C^{min} amounts to assuming that from a societal viewpoint the marginal value of grain becomes perfectly inelastic at the critical consumption level. This implies an upward shift in the carryover demand schedule and, hence, D up to, say, D'. To see this, suppose that in figure 2, D^c becomes less elastic for low consumptive levels. Then if p^1, h^1 occurs, for example, the domestic price will be greater than d^1. This implies that the expected domestic price increases and hence the carryover demand schedule must shift up.

To maintain food consumption above C^{min}, the country should increase imports and carryovers when world prices and/or domestic supply levels are favorable (for example, p^2 in figure 6). In the event of unfavorable world prices or domestic supply levels, the country

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[4] Numerical computations in Knapp suggest that the optimal storage capacity is substantially greater with borrowing/saving of foreign exchange than without. This provides further evidence of complementarity.

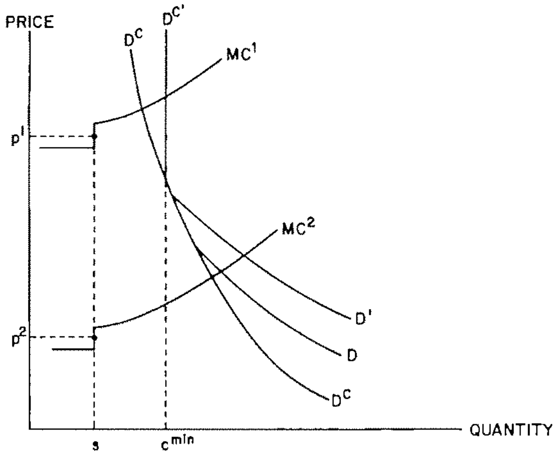

Figure 6. Policies for maintaining consumption above C^{min}

obviously must increase its imports to maintain the critical consumption level (e.g., p^1 in figure 6). If this implies a relatively large import bill, then foreign exchange should be borrowed.

Concluding Remarks

In the absence of foreign exchange borrowing/saving, the principles of optimal grain stockpiling in open economies are readily inferred from figure 3. Generally speaking optimal carryovers increase with domestic supply and decrease with the world price. Optimal imports decrease as domestic supplies and/or world prices increase.

The situation becomes more complicated when foreign exchange can be transferred between periods. Foreign exchange is borrowed when expenditures are relatively high and saved when expenditures are relatively low. Compared to the case of no borrowing/saving of foreign exchange, optimal carryovers are the same or greater when foreign exchange is borrowed and the same or less when foreign exchange is saved. Grain reserves and borrowing/saving of foreign exchange thus represent two inventory systems which both complement and substitute for one another.

More generally, the analysis illustrates three possible instruments which countries can use to mitigate the consequences of unexpected fluctuations in domestic harvests and world prices. They can modify trade levels, put grain into storage, or shift foreign exchange between time periods. Which particular combination will be used depends on the conditions prevailing at a point in time, the parameters of the problem, and the objectives being pursued.

Finally, the graphical analysis in this paper is a useful approach to the analysis of grain reserves. Considerable insight into a nontrivial problem in stochastic control is obtained using only basic economic principles. The approach was used to characterize optimal storage rules. It can also be used for sensitivity analysis and for determining the consequences of other domestic and international stabilization schemes.

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Asymmetry in Retail, Wholesale, and Shipping Point Pricing for Fresh Vegetables

Ronald W. Ward

The linkage among retail, wholesale, and shipping point prices for a select group of fresh vegetables is measured using Wolffram's asymmetry model. Procedures for dealing with discontinuous time series are shown, and Granger's causality test is used to show the direction of the price linkage. Wholesale prices are shown to lead both retail and shipping point prices. Asymmetry in the retail-wholesale response indicates that wholesale price decreases are reflected at the retail more so than are wholesale price increases. Wholesale price decreases are more fully passed through to the shipping point relative to wholesale increases.

Key words: asymmetry, fresh vegetables, prices, retail-wholesale-shipping linkage.

The linkages among retail, wholesale, and shipping point prices continues to be of considerable economic interest. As raw food products are transformed through packaging, distribution, and related services, the evidence of direct relationships among prices at different levels of exchange becomes increasingly difficult to evaluate. The extent of price change transmission through the vertical market system is particularly important at the end points. Producers view themselves as the residual claimants on the value of products, while consumers fear continually rising prices of many food items. Agricultural products having many uses and requiring considerable transformation should show weak price relationships among the exchange points. In contrast, price linkages should be stronger for perishable products requiring a minimal transformation.

Price leads and lags among retail, wholesale, and shipping points may arise, in part, because of differences in the assimilation of market information. Understanding these leads or lags is important to evaluating pricing efficiency among markets. The speed of price adjustments between vertical exchange nodes provides clues about structural rigidities and cumulative effects of price changes.

In this paper the price linkages among retail, wholesale, and shipping points will be analyzed in order to provide additional empirical evidence about price transmission. A distributed lag model is developed, and asymmetry in the price linkages is considered. The empirical analysis is limited to a few fresh vegetables, where price information is available at each point of exchange. Data include both continuous and discontinuous series, and econometric procedures for dealing with the data gaps are discussed. The vertical price linkages for fresh vegetables should be reasonably strong since these products have a limited number of uses and are transformed only via packaging. Since supplies are inelastic, shifts in demand should cause direct price adjustments throughout the vertical structure. The actual price responses will depend on the quality and timing of information received at each pricing level.

Price Transmission Model

Information exists throughout the market system and retail (R), wholesale (W), and shipping point (S) prices are some functions of this information. This information flow throughout the vertical system may not be equal and traders' abilities to assimilate and/or respond to market signals can differ at each exchange point. Structural differences and diversity at each level can influence how quickly prices

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reflect changes in market conditions. Clearly, the retail, wholesale, and shipping price series must be related since they are functions of the same basic information.

Complete quantification of market information is impractical and not essential to understanding pricing relationships. One can turn directly to the three price series. Arguments exist for both leads and lags among the three series. Most studies point to a causal linkage from shipping point to wholesale to retail (Heien, Silver and Wallace). Conditions can exist that suggest a different linkage. If the wholesale market quickly assimilates market signals from both consuming and producing points, the wholesale price may lead both the retail and shipping point prices. The period for measuring responses also would influence any measurement of leads. Likewise, product perishability may add importance to the wholesale function. Excess accumulation of perishable products at wholesale may directly affect shipping point prices. Ultimately, the existence of leads or lags is an empirical question and will be deferred until later.

Initially consider the situation where $R = f(W)$. The total retail response to wholesale price changes may not be immediate, but distributed over time. Heien suggested that the cost of making retail price adjustments and concern over pricing stability may create lags at retail. Furthermore, the response to rising prices at wholesale can differ from price declines. The retail market structure could be sufficiently oligopolistic so that price stickiness occurs, producing asymmetric response to wholesale price changes.[1]

Equation (1) illustrates the general case where the retail price is related to the wholesale price through a distributed lag function.

$$(1) \qquad R_t = \alpha_{0t} + \sum_{j=1}^{k} \alpha_j W_{t-j+1} + \epsilon_t.$$

If asymmetry occurs, then α_j differs depending on whether $W_t \gtreqless W_{t-1}$. Papers by Wolffram, Houck, and Young have dealt with estimating asymmetric parameters. Using Young's framework, equation (1) can be written as

$$(2) \quad R_t = \beta_{0t} + \sum_{j=1}^{k} (\alpha'_j W'_{t-j+1} + d''_j W''_{t-j+1}) + \epsilon_t,$$

where

$$W'_t = \sum_{i=0}^{t} (W_{t-i} - W_{t-i-1})Z'_{t-i},$$

$$W''_t = \sum_{i=0}^{t} (W_{t-i} - W_{t-i-1})Z''_{t-i},$$

$$Z'_{t-i} = \begin{cases} 1 \; W_{t-i} \geq W_{t-i-1} \\ 0 \text{ otherwise, and} \end{cases}$$

$$Z''_{t-i} \quad \begin{cases} 1 \; W_{t-i} < W_{t-i-1} \\ 0 \text{ otherwise.} \end{cases}$$

Using Gollnick's derivation, it also follows that (2) can be simplified to

$$(3) \quad R_t = \beta_{0t} + \sum_{j=1}^{k} [\alpha'_j(W_{t-j+1} - W_0) + (\alpha''_j - \alpha'_j)W''_{t-j+1}] + \epsilon_t.$$

The estimate of $(\alpha''_j - \alpha'_j)$ gives a direct test of the asymmetry condition.[2] Note that α'_j measures the response to rising wholesale prices, while α''_j relates to a declining wholesale price.

Polynomial lags can be adapted easily to the two distributed lag series in equation (3). If one is willing to assume that the peak retail response to a wholesale price change is immediate, then a first-degree polynomial is appropriate. Letting ϕ_j be some weighting of the lags, the polynomial in (4) could be incorporated into (3). Only four parameters are unknown in (4) in contrast to $2k$ unknown pricing parameters in (3). Hence, the estimation problem is greatly simplified with (4).

$$(4) \qquad \alpha'_j = \lambda'_0 + \lambda'_1\phi_j, \text{ and}$$
$$\alpha''_j - \alpha'_j = \lambda''_0 + \lambda''_1\phi_j.$$

For some products, gaps in the price series

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[1] The top four food retailers, on the average, held approximately 50% of the market in 218 major metropolitan areas in 1963. Concentration was above 65% in sixteen of the markets (Bucklin, p. 125). Little change in concentration has taken place since then (Grinnell 1980b, p. 7). Competition in retailing is a local and regional affair where firms are aware of the pricing tactics used (Bucklin, p. 130). In contrast to the oligopolistic argument, Baumol, Quandt, and Shapiro suggest that while lsupermarkets are aware of each other, they take no account of competitors' reaction because of cost, complexity, and data imperfections (p. 347). Also, see Grinnell for a recent discussion of food retailers' pricing policies (1980a, p. 10–11).

[2] Consider a simple model where $R_t = \pi_0 + \pi_1 W_t$. Wolffram's model, allowing for asymmetry, would be $R_t = \pi_0 + \pi'_1 W_t + \pi''_1 W''_t$, where W'_t and W''_t are defined in equation (2) of the text. Gollnick clearly shows that $W_t = W_0 + W'_t + W''_t$ or $W'_t = W_t - W_0 - W''_t$. Substitution for W'_t in the functional equations gives the estimable model $R_t = \pi_0 + \pi'_1(W_t - W_0) + (\pi''_0 - \pi'_1)W''_t$. This equation is simply expanded to a distributed lag form in equation (3) (Young, p. 178).

Table 1. *F*-statistic for Granger's Causality Test

	Prefilter[a] Level "k"	Retail → Wholesale		Wholesale → Retail		Wholesale → Shipping		Shipping → Wholesale	
		F-Statistic[b]	ρ	F-Statistic	ρ	F-Statistic	ρ	F-Statistic	ρ
Carrots (Chicago)	.00	.419	.278	24.891	.303	4.586	.533	3.434	.502
	.25	.652	−.218	14.861	−.135	4.156	−.024	2.235	−.061
	.75	1.046	−.592	3.664	−.631	.777	−.647	.545	−.621
	1.00	1.238	−.064	3.281	−.655	.707	−.669	.563	−.646
Carrots (New York)	.00	2.064	.224	3.544	.064	1.124	.321	1.914	.386
	.25	2.785	−.239	2.324	−.369	2.268	−.113	1.949	−.064
	.75	1.305	−.615	2.271	−.679	5.762	−.517	.364	−.504
	1.00	.919	−.638	2.631	−.699	6.309	−.542	.249	−.525
Celery (Chicago)	.00	3.037	.219	13.091	.193	8.803	.419	1.300	.233
	.25	3.978	−.156	8.582	−.184	6.199	−.253	1.387	−.235
	.75	4.030	−.439	3.472	−.539	2.803	−.573	.292	−.597
	1.00	3.278	−.566	3.997	−.559	2.865	−.591	.109	−.617

Note: The results for all series studied are available upon request (USDA). The only exception to the implied linkage occurred with some of the lettuce series where unidirectional relationships were indicated.

[a] See Bishop for a discussion of the filtering procedure.

[b] Sample sizes are reported in tables 2 and 3. In each situation comparison of the calculated F to a table $F \simeq 3.00$ is near the 95% confidence level.

exist because supplies do not flow to market throughout the year. For example, if a product is marketed only during the first six months of each year, carryover effects would not occur during the initial months of each season. At each season's outset, the only relevant price information would be current wholesale prices. Later in the season, current retail prices may be influenced by prior wholesale prices. The distributed lag model specified earlier must reflect whether or not lagged information exists at period t^*. If t^* is the first period of a new season and the series is discontinuous, no lag information exists. During the next month, the price information from t^* would enter the analysis for $t^* + 1$. Likewise, during $t^* + 2$ both prices from t^* and $t^* + 1$ enter the analysis.

The presence or absence of prior information can be handled with dummy variables. If the distributed lag model is estimated with three lags, then three dummy variables can be defined to indicate if any particular lag should be included in the model. The dummy variables shown in equation (5) illustrate the concept for a season when a data gap exists between the last value of the prior season and the first value of a new season. Each row represents one observation containing the current period and three lags. Each D_j is multiplied times the corresponding W_{t-j+1} in (3), assuming three lags. W_t always enters the model, while W_{t-1} enters after the first period t^*. Finally, by the fourth period in the example, all three lags are included. The matrix **D** may differ with each commodity depending on the discontinuity of each series.

$$\mathbf{D} = \left[\begin{array}{cccc} D_1 & D_2 & D_3 & D_4 \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{array}\right] \tag{5}$$

Econometric Linkage Model

Instead of t observations as in equations (2) and (3), now assume that there are l seasons and t observations in each season. Each variable then carries the additional subscript l, and the relevant parameters are assumed constant across seasons (Wolffram, p. 358). With this model, the Wolffram asymmetric procedure starts over with each season. The starting value for W' and W'' is W_{l0}. Incorporating (4) and (5) into (3) and accounting for the various seasons, a general model for estimating the price linkage follows in equation (6).

Table 2. **Asymmetric Price Linkage between Wholesale and Retail Prices**

			Parameter Estimates[a]					
Commodity	Units	City	Intercept	H_1	H_2	H_3	H_4	T
Carrots	$/48-lb. bags	Chicago	10.9881 (12.0633)	.8050 (6.6157)	−.5482 (−3.9637)	−.1322 (−.7173)	.1666 (.8681)	.0487 (1.3678)
Celery	$/60-lb. crate	Chicago	12.3069 (11.0806)	.6188 (7.582)	−.2705 (−2.5916)	.4121 (2.2306)	−.4411 (2.2991)	.0392 (.6119)
Cabbage	$/50-lb. crate	Chicago	3.4523 (4.1516)	.4850 (2.5729)	.1060 (.4661)	.6136 (2.6100)	−.3745 (−2.1933)	.0220 (3.0154)
Corn	$/crate	Boston	2.5296 (5.8089)	.2259 (1.6135)	−.0394 (−.2482)	.5519 (5.8992)	−.3805 (−5.1458)	.0278 (6.3210)
Cucumbers	$1 ¼ bushel	New York	9.0729 (15.5350)	.5439 (10.5365)	−.4567 (−7.4135)	.0284 (.4881)	.1109 (2.1028)	.0467 (7.8122)
Green peppers	$/30 lbs.	New York	8.9460 (14.1133)	.4351 (7.1053)	−.2154 (−2.6297)	.3153 (3.9133)	−.2089 (−3.3428)	.0428 (6.8542)
Potatoes	$/100 lbs.	Los Angeles	6.4467 (10.6001)	.5754 (3.3506)	−.5113 (−2.5289)	.2969 (2.6525)	−.1890 (−2.0573)	.0243 (2.8019)
Tomatoes	$/20-lb. carton	Chicago	4.2280 (3.8856)	.5085 (4.5462)	−.5049 (−4.0737)	.3803 (2.4714)	−.2728 (−2.5729)	.0596 (7.7520)
Tomatoes	$/20-lb. carton	New York	4.2672 (5.5065)	.3285 (3.1906)	−.2702 (−2.4400)	.5776 (5.2482)	−.3364 (−4.3107)	.0442 (4.6302)

Note: Data obtained from USDA.

[a] See equation (6) for interpreting H; t-values shown in parentheses.

[b] Mean lags and cumulatives are not calculated because H_2 was insignificant and of the wrong sign.

$$(6)\quad R_{lt} = \lambda_{0(lt)} + \lambda'_0 H_{1(lt)} + \lambda'_1 H_{2(lt)} + \lambda''_0 H_{3(lt)} + \lambda''_1 H_{4(lt)} + \epsilon_{lt},$$

where

$$H_{1(lt)} = \sum_{j=0}^{3} [W_{l(t-j)} - W_{l(0)}] D_{j(lt)},$$

$$H_{2(lt)} = \sum_{j=0}^{3} [W_{l(t-j)} - W_{l(0)}] \phi_j D_{j(lt)},$$

$$H_{3(lt)} = \sum_{j=0}^{3} W''_{l(t-j)} D_{j(lt)},$$

$$H_{4(lt)} = \sum_{j=0}^{3} W''_{l(t-j)} \phi_j D_{j(lt)}.$$

While (6) is illustrated assuming the retail market lags the wholesale market, a precise test of the leads or lags for both retail and shipping points must be made.[3] Furthermore, the function ϕ_j must be specified.

Retail, wholesale, and shipping point price data on seventeen fresh vegetables were included in the study. Retail prices from a number of cities were reported for some of the vegetables. Of these, carrots, celery, and lettuce were the only fresh produce supplied continuously throughout the season. Empirical evidence for measuring leads or lags can be made using Granger's causality test on these continuous series (Bishop). Granger's test presumes that causality may flow in either direction between two variables (Granger). Applying the Granger procedure and using the appropriate F-test, the direction of causality becomes clear. Table 1 includes the F-values calculated for causality between retail-wholesale and wholesale-shipping point.

Although a total of eleven continuous data series was available, only a sample of the Granger tests are reported in table 1. The empirical evidence from table 1 and from results not reported suggests that retail prices tend to lag wholesale prices. Such results are consistent with most other studies (Heien, Silver). In contrast, the results for the wholesale-shipping point analysis suggest that the wholesale price series led shipping point prices. Wholesale markets are generally more concentrated, and information can be more readily assimilated. In contrast, shipping points are generally diverse, and information flows are less complete. Although beyond the scope of this analysis, a detailed study of buyers versus seller concentration could add more insight into this observed relationship. Also, the geographical concentration of suppliers likely would influence this price linkage.

The monthly leads must arise where information is first and most quickly assimilated. While some exceptions are evident, the lead linkage from wholesale to both retail and shipping points is assumed for the remaining analysis.[4]

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[3] Each H is derived by summing over j. It will always be true that $D_{j(lt)} = 0$ when $j > t$.

[4] Monthly retail prices are the averages over Tuesday, Wednesday, and Thursday's prices for each week within a month. Wholesale prices are averaged over each Tuesday's price for the same week that retail prices are collected. The shipping point price is the monthly average of the prices for each week preceding the wholesale and retail prices. Hence, the monthly shipping point

Table 2. (Continued)

Statistics			Season		Mean Price			Mean Lag		Cumulative	
Observed	R^2	F	1st	Last	Retail	Wholesale	Shipping	Rising	Falling	Rising	Falling
114	.886	173.19	Jan	Dec	10.361	6.144	4.306	.443	.816	1.191	1.279
120	.885	179.94	Jan	Dec	13.515	7.305	4.150	1.079	.405	1.474	1.489
63	.792	43.31	Dec	May	8.816	4.357	2.829	**	*	*	*
46	.861	49.45	Jan	June	7.929	5.536	3.881	1.381	.882	.758	1.557
74	.826	64.69	Nov	May	16.004	10.148	7.668	.138	.714	.631	1.009
69	.831	62.04	Jan	June	16.147	9.909	8.015	.976	.820	.943	1.431
77	.509	14.74	Sept	Apr	10.588	6.522	4.545	.100	.165	.639	1.044
42	.764	23.32	Jan	May	10.052	7.138	5.816	.007	.111	.512	.999
47	.805	33.97	Jan	May	12.371	8.122	6.034	.151	.491	.387	1.378

The polynomial specification in equation (4) implicitly assumes that the peak effects occur at the outset followed by a smooth decline. Preliminary results consistently suggested a geometric decay function. While a range of values for ϕ_j that have similar geometric decay properties can be adapted to (4), the final specification is where $\phi_j = \sqrt[3]{j}$ and $j \geq 0$ (Ward and Myers, p. 5). Using this specification, $\partial\alpha'_j/\partial_j < 0$, $\partial^2\alpha'_j/\partial_j^2 > 0$, $\partial\alpha''_j/\partial_j < 0$, and $\partial^2\alpha''_j/\partial_j^2 > 0$. The carryover effect from previous price levels declines from the outset. Both α'_1 and α''_1 represent the immediate effect of price changes at wholesale.

The empirical results using equation (6) with a subset of fresh vegetable data are reported in tables 2 and 3, table 2 giving the wholesale-retail linkages and table 3, the wholesale-shipping point relationship.[5] In both tables, parameter values for H_1 and H_2 correspond to λ'_0 and λ'_1 from equation (4), and H_3 and H_4 correspond to λ''_0 and λ''_1. The first two equations are for commodities with continuous data sets, while the remaining estimates are based on discontinuous data. In general, the results were consistent across the items studied, and all statistical values can be readily interpreted in terms of significance and economic implications.

Asymmetric Linkage

The significance tests on H_3 and H_4 in tables 2 and 3 are direct tests of asymmetry in retail and shipping point price responses to wholesale price changes. The immediate effect of a wholesale change is α'_1 for rising prices and α''_1 for falling prices, where $\alpha'_1 = \lambda'_0$ and $\alpha''_1 = \lambda'_0 + \lambda''_0$. The retail results, without exception, lead to one of two conclusions. Either the responses are symmetric, or retail markets respond more to declining wholesale prices than to rising prices. Symmetry in the initial period exists for the carrot and cucumber markets, but H_3 is positive and significant for the remaining items. Even though retail responses vary across commodities, the general conclusion of significant asymmetry holds for the majority of products studied.

The asymmetric responses provide new insight into the performance of the wholesale-retail market for this commodity sample and, possibly, for perishables in general. First, the models point to some retail resistance to price rises.[6] This may be explained partially by re-

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price is based on an average over a weekly series that lags the retail and wholesale by one week.

Some bias in the relationship between prices at different exchange points could arise with this weekly lag. Suppose that prior results suggest that Y_t leads X_t and the data are reported in three alternative series, i.e., (Y_t, X_t), (Y_t, X_{t-1}), or (Y_t, X_{t+1}). Using Granger's causality test, the first series would have no effect on the results, the second series would be biased against the prior lead of Y_t over X_t, and the third series would be biased in support of the lead. Subsequent analyses will show that the wholesale price (e.g., Y_t) leads the shipping price (e.g., X_t). Both are monthly averages but the X series does have a one week built-in lag. If the week lag affects the results, it is biased against showing that Y_t leads X_t. Also, the Granger test relates to monthly leads and lags, while the differences in series is limited to one week. Most of the effects of one week is likely averaged out when calculating the monthly average.

[5] Only a subsample of fresh produce results are reported in tables 2 and 3. Since most estimates not reported were similar to those reported, this subsample is adequate for presenting the study's general conclusions.

[6] One may question this result since, in general, supermarkets often price using standard margins over invoice cost. Holdren's studies showed that for fresh fruits and vegetables the pricing formula was much less structured (p. 85). Most produce prices are not highly competitive, margins are high, and price dispersions are wide across firms. Asymmetry in the wholesale-retail margin is discussed in Holdren, where greater differences are seen with the more aggressive firms (p. 93–94).

Table 3. Asymmetric Price Linkage between Wholesale and Shipping Point Prices

		Parameter Estimates						Statistics			Mean Lag		Cumulative	
Commodity	City	Intercept	H_1	H_2	H_3	H_4	r	Obs.	R^2	F	Rising	Falling	Rising	Falling
Carrots	Chicago	5.4102 (11.7258	.6663 (10.8111)	−.5569 (−7.9506)	−.1098 (−1.1768)	.1347 (1.3851)	.0143 (.7933)	117	.842	118.51	.141	.257	.776	.715
Celery	Chicago	4.8053 (8.6805)	.5074 (10.6146)	−.3072 (−5.2526)	.2566 (2.4660)	−.2639 (−2.4766)	.0185 (.5358)	129	.843	132.14	.711	.282	.893	1.001
Cabbage	Chicago	.8008 (1.7082)	.5304 (4.9918)	−.2334 (−1.8199)	.3913 (2.9520)	−.2506 (−2.6033)	−.0028 (−.6834)	64	.729	30.79	1.074	.915	1.258	1.895
Corn	Boston	1.2132 (3.6187)	.4566 (5.5910)	−.3890 (−3.9301)	.2569 (3.6938)	−.1923 (−3.5708)	.0150 (4.7473)	55	.801	38.53	.129	.156	.524	.846
Cucumbers	New York	4.5883 (8.0132)	.5655 (11.1726)	−.5171 (−8.5620)	−.0071 (−.1248)	.0650 (1.2580)	.0129 (2.2053)	55	.742	39.09	.079	.160	.614	.665
Green peppers	New York	4.8194 (7.1722)	.6976 (10.7453)	−.5698 (−6.5634)	.0145 (.1703)	.0056 (.0840)	.0096 (1.4461)	69	.793	48.18	.155	.175	.825	.861
Potatoes	Los Angeles	2.1681 (5.8939)	.5264 (5.0689)	.4108 (−3.3577)	.3140 (4.6185)	−.1815 (−3.1910)	−.0037 (−.6895)	75	.615	22.04	.205	.369	.651	1.183
Tomatoes	Chicago	1.4670 (2.2078)	.5776 (6.1856)	−.5465 (−5.2698)	.4167 (4.5057)	−.2505 (−3.8610)	.0107 (1.6203)	45	.647	14.33	.051	.166	.609	1.192
Tomatoes	New York	1.1229 (1.8554)	.4359 (5.4196)	−.4003 (−4.6286)	.4406 (5.1771)	−.2350 (−3.8558)	.0056 (.7564)	47	.729	22.09	.075	.330	.472	1.194

sistance to raising the price of perishable products that require high turnover. Rising prices could reduce retail sales and increase the incidence of spoilage. Second, an oligopolistic structure among large retail outlets suggests upward price stickiness and, hence, resistance to price increases.

Consumers generally can expect to benefit immediately from falling wholesale prices because price decreases tend to be rapidly passed through to retail. In contrast, price increases are passed through to a much lesser degree during the same period. The retail price response to falling wholesale prices is particularly important to industries which rely on price promotions initiated at the wholesale level since the lower prices generally would be passed on to the consumer. On average, the retail response to rising wholesale prices in the current period is approximately 50% of the retail response to equivalent falling wholesale prices.

Asymmetry is also evident in the wholesale-shipping point relationships, table 3. The estimators indicate that wholesale price decreases are more fully felt at the shipping point than are price increases. Recall that only the current period effect is being considered. In contrast to the results showing the consumer to benefit potentially from asymmetry, this latter linkage should raise concern among producers since the results suggest that wholesale price increases are not immediately passed back to the shipping point to the same degree as are decreases.

Lag Distribution

The lag distributions in equation (4) were specified as a first-degree polynomial, where $\phi_j = \sqrt[3]{j}$. Evidence of lag responses between retail and wholesale differed depending on whether wholesale markets were rising or falling. The existence of a lag during rising markets was questionable for cabbage and corn, while evidence of some decay remained apparent for the other products. In contrast, significant lag responses were observed for every item during periods of falling prices.

Considerable differences in lag responses occur across commodities, as shown by the differences in mean lags, tables 2 and 3 (Pindyck and Rubinfeld, p. 232). In all cases, the carryover effect is generally small, ranging from nearly zero for tomatoes to more than a one-month mean lag for corn. In most cases, decays are generally very rapid. Similar mean lags appear for the shipping point-wholesale markets, table 3. Again, the carryover price effect is small. In general, the major responses to wholesale price changes is immediately evident at both retail and shipping points.

The cumulative effect of a wholesale price change was calculated as either $\sum_{j=1}^{\max 4} \alpha'_j$ for a rising market or $\sum_{j=1}^{\max 4} \alpha''_j$ for a falling market. Each summation was taken over the α_j values up to the point where $\alpha'_j < 0$, $\alpha''_j < 0$, or $j = 4$, whichever occurred first. These cumulative effects are shown in tables 2 and 3. Without exception, the cumulative effect on the retail market was greater for declining wholesale prices. That is, for this sample of commodities, the model indicates that the full price decline eventually is reflected in retail price changes. In contrast, a wholesale price increase is not always fully reflected at the retail. The New York fresh tomato market is particularly noteworthy because the difference between the cumulatives is quite large.

The differences in cumulatives for the shipping point, table 3, are not as pronounced as the wholesale-retail differences. In general, the asymmetry results at the shipping point indicate that declining wholesale prices tend to be more fully passed through to the shipping point than for wholesale price increases. However, the difference is minimal for several of the products.

Spread Adjustments

The final model included a trend adjustment to measure the tendency for spreads between wholesale, retail, or shipping point prices to change. This is shown by T in both tables 2 and 3. The empirical results clearly show that the retail-wholesale price spread has widened over time. This is as expected because of the increases in service and distribution costs. Spread adjustments between the shipping point and wholesale markets are mixed and most T parameters are statistically insignificant. It is apparent that the major portion of the spread increase from shipping point to retail is occurring at the retail end.

Summary

This price linkage model used Wolffram's asymmetry procedure with a distributed lag model estimated over continuous and discontinuous data series. Price transmission measurements were made for a subset of fresh vegetables. The results show that the wholesale market tends to be a major node for pricing. Both retail and shipping point prices generally lag wholesale price changes.

The asymmetric results are particularly interesting because they suggest a deviation from the traditional concept of constant percentage markup. For this sample of fresh vegetables, the evidence clearly shows that price changes are not transmitted throughout the vertical system, at least not in the same time period. Wholesale price increases are not totally reflected at the retail, whereas retail prices tend to adjust to lower wholesale prices. In contrast, shipping point prices tend to reflect more fully wholesale price decreases relative to increases.

The analysis offered alternative reasons for the asymmetry, ranging from the structural considerations to the nature of the products. Perishability may be a major contributing factor.

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The Structure of Food Demand: Interrelatedness and Duality

Dale M. Heien

This paper presents a new empirical demand system which mitigates the effects of multicollinearity while facilitating the measurement of interrelatedness. Duality theory is used to derive the inverse demand functions. Using data on fourteen food items a complete set of demand equations is estimated in both quantity and price dependent forms. The model is used to test for the theoretical restrictions of homogeneity, additivity and negativity, as well as the habit formation hypothesis. A comparison is made between these results and those of Brandow and George and King.

Key words: demand systems, flexibilities and elasticities, habit formation, interrelatedness, multicollinearity.

In analyzing food demand, researchers have encountered two recurring difficulties. The first arises from the desire to measure the interrelatedness among farm products. Substantial substitutability exists between various members of the food group, resulting in a high degree of collinearity among food prices. This collinearity has led to severe estimation problems. The classic work by Brandow, which combined single-equation and complete systems approaches, was a pioneering effort at measuring interrelatedness while overcoming the multicollinearity problem. The Frisch approach, utilized by Brandow and George and King, depended on the assumption of additivity and required measurement of the marginal utility of money.

The second recurrent problem is often referred to as the "price-dependent" nature of agricultural commodities. Early demand analysts, such as Sewell Wright and Henry Moore, recognized that for many agricultural products, the quantity supplied—and hence demanded—was predetermined. As a result, short-run demand variations result in price changes. Price dependency, as further developed by Fox and Waugh, was viewed from a statistical perspective, leaving the theoretical edifice incompletely developed. This void has led to ad hoc specifications and ambiguous interpretation of results.

This paper introduces an applied demand model which mitigates the effects of multicollinearity while measuring the interdependence among commodities. Duality theory is used to derive the price-dependent form of the model and its restrictions. Last, the model is estimated in the price- and quantity-dependent modes using postwar data on sixteen commodities.

Theoretical Development

Consider a consumer who arranges the commodities under his consideration into various groups. Strotz called this arrangement a utility tree. Denoting the *i*th good in the *s*th branch as q_{si}, the sub-utility function for a group may be written as

$$U_s = \left(\sum_{i \in s}^{n_s} \beta_{si} q_{si}{}^{\rho_s} \right)^{1/\rho_s}, \tag{1}$$

where $\sigma_s = \dfrac{1}{1 - \rho_s}$ is the Allen elasticity of substitution (AES) between goods in the *s*th branch, and n_s is the number of goods in that branch. These subgroups can then be aggregated into an overall utility function,[1]

$$U = \left(\sum_{s=1}^{S} \alpha_s U_s{}^{\rho} \right)^{1/\rho}, \tag{2}$$

where S refers to the total number of groups

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[1] This function, called the *S*-branch utility tree, is treated in detail in Brown and Heien. The function given by (1) and (2) is separable, implying that the marginal rate of substitution between goods in two different groups is independent of the level of consumption of goods not in those groups.

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and $\sum_{s=1}^{S} n_s = n$ is the total number of goods. Uzawa has shown the AES between q_{si} and q_{rj} is

$$\sigma_{si,rj} = \begin{cases} \sigma \text{ for } r \neq s \\ \sigma + \dfrac{1}{W_s}(\sigma_s - \sigma) \text{ for } r = s, \end{cases} \tag{3}$$

where

$$W_s = \sum_{j\epsilon s}^{n_s} p_{sj}q_{sj}/m \quad \text{and} \tag{4}$$

$$m = \sum_{s=1}^{S} \sum_{j\epsilon s}^{n_s} p_{sj}q_{sj}. \tag{5}$$

Maximization of (2) subject to (5) results in demand relationships of the form,

$$q_{si} = (\beta_{si}/p_{si})^{\sigma_s} \alpha_s^{\sigma} X_s^{-1} Z_s M m, \tag{6}$$

where

$$X_s = \sum_{i\epsilon s}^{n_s} (\beta_{si}/p_{si})^{\sigma_s} p_{si}, \tag{7}$$

$$Z_s = \alpha_s^{\sigma} X_s^{\frac{\sigma - 1}{\alpha_s - 1}}, \quad \text{and} \tag{8}$$

$$M = \sum_{r=1}^{S} Z_r. \tag{9}$$

The price and income elasticities for (6) are given in appendix A.1–A.4. These relations possess the well-known theoretical restrictions, given in appendix B.1–B.4. The assumption of separability shows up clearly in the elasticity expressions. As shown in Deaton and Muellbauer, separability results in a two-tier structure for the elasticity matrix; one tier for within group needs, another for between group goods. Furthermore, the separability assumption places restrictions on the between-group substitution effects. In this case, all goods from different groups must be substitutes, and the magnitude of elasticity is proportional to the budget share. Imposing this assumption may appear overrestrictive. However, two important advantages are gained. First, the grouping concept provides the framework for overcoming the multicollinearity problem. More general systems require more parameters and, hence, pose formidable estimation problems. Also, more general systems are not mathematically tractable. For example, the translog utility function will not yield analytic expressions for the demand relations. The notion that intragroup price effects are proportional to budget shares is consistent with Marshall's dictum that the own-price elasticity is (*inter alia*) proportional to the budget share. Second, the specification given here provides a framework to test the appropriateness of the S-branch specification. While an assumption such as separability can never be tested in general, the S-branch does provide a particular test.

The demand model given by (6) applies to an individual consumer. However, data used to estimate such models are often market aggregates. When dealing with market data, demand is sometimes considered to be predetermined because of fixed short-run supply. When this occurs, statistical considerations suggest some form of price dependency.[2] Fortunately, duality theory shows how to treat this case in a theoretically consistent manner.

Begin by substituting (6) into (1) and then (2) to obtain the indirect utility function,

$$U^I = \left(\sum_{r=1}^{S} \alpha_r X_r^{\frac{\rho}{\sigma_r - 1}} \right)^{1/\rho} m. \tag{10}$$

Minimization of (10) subject to (5) yields the inverse demand equations,

$$p_{si} = \beta_{si} q_{si}^{\rho_s - 1} \alpha_s Y_s^{-1} W_s N m, \tag{11}$$

where

$$Y_s = \sum_{i\epsilon s}^{n_s} \beta_{si} q_{si}^{\rho_s}, \tag{12}$$

$$W_s = \alpha_s Y_s^{\frac{\rho}{\rho_s}}, \text{ and} \tag{13}$$

$$N = \sum_{r=1}^{S} W_r. \tag{14}$$

Following Hicks' terminology, relations such as (11) are termed p-dependent, while those given by (6) are q-dependent. The flexibilities of price with respect to income and quantities are given in appendix A.8–A.11. A set of theoretical restrictions similar to those of q-dependent relations, given in appendix B.5–B.8, apply to the inverse demand equations. It should be noted that while B.1 refers to the zero degree homogeneity of prices and income in q-dependent relations, B.5 refers to the homogeneity of prices with respect to quantities in the p-dependent relations. The unit homogeneity of prices with respect to income in the p-dependent relations is the zero degree homogeneity property of the q-dependent functions.

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[2] Although statistical considerations have been the main argument for price dependency, they also support the quantity-dependent approach. Quantities entering food demand relations are subject to substantial measurement error partly because of the manner in which they are built up from the farm level and partly because of sampling error. Retail prices on the other hand are subject to rigorous quality control and are probably much more accurate measures.

Model Specification

The double-log demand model has found wide empirical acceptance; and in its most general form it may be written,

$$(15)\quad \ln q_{si} = \sum_{r=1}^{S} \sum_{j \epsilon s}^{n_s} \alpha_{si,rj} \ln p_{rj} + \alpha_{si} \ln m.$$

Noting that $\alpha_{si,rj} = e^{P}_{si,rj}$ and $\alpha_{si} = e^{M}_{si}$, substitution of the S-branch elasticities (A.1–A.4) into (15) gives

$$(16)\quad \ln q_{si} = (\sigma - 1) \ln P + (\sigma_s - \sigma) \ln P_s - \sigma_s \ln p_{si} + \ln m,$$

where

$$(17)\quad P = \prod_{r=1}^{S} \prod_{j \epsilon r}^{n_r} p_{rj}^{\bar{w}_{rj}}, \text{ and}$$

$$(18)\quad P_s = \prod_{j \epsilon s}^{n_s} p_{sj}^{\bar{W}_{sj}}.$$

The double-log demand function given above is considered an approximation to a more general demand function. In this sense it is similar to the double-log functions of the Rotterdam model. Relation (16) is a substantial simplification from (15). Demand for the sith good has been reduced from a function of all prices and income to a function of a geometric price index of all goods, a geometric price index of goods in the same branch, the own-price and income. The number of parameters has been reduced from $n + 1$ to two. For even moderate size systems, this represents a substantial reduction and should alleviate multicollinearity. Moreover, this system permits a theoretical analysis of how the various price indexes (the P and P_s's) are constructed and how the underlying utility function is structured. The complete system restrictions given by B.1–B.4, with one exception, also will be satisfied by (16). As is apparent, (16) requires that the w_{rj}'s and W_{rj}'s (see A.5–A.7) appear on the right-hand side in the computation of P and P_s. For the S-branch system, the respective budget shares are not constants but are functions of prices. If, for estimation purposes, the actual w_{rj}'s are replaced by their sample means ($\bar{w}_{rj}$'s), then the restrictions will hold only to the extent that each sample budget share equals the actual budget share. Hence, this system is termed the almost complete system (ACS).

Proceeding in an analogous manner for the inverse demand relations, let[3]

$$(19)\quad \ln z_{si} = \sum_{r=1}^{S} \sum_{j \epsilon r}^{n_r} f_{si,rj} \ln q_{rj},$$

and substituting A.8–A.11 into (19) gives

$$(20)\quad \ln z_{si} = -\rho \ln Q - (\rho_s - \rho) \ln Q_s + (\rho_s - 1) \ln q_{si},$$

where

$$(21)\quad Q = \prod_{r=1}^{S} \prod_{j \epsilon r}^{n_r} q_{rj}^{\bar{w}_{rj}}, \text{ and}$$

$$(22)\quad Q_s = \prod_{j \epsilon s}^{n_s} q_{sj}^{\bar{W}_{sj}}.$$

Equation (20) gives the normalized price of the sith good as a function of the quantity demanded of that good, a quantity index (Q_s) of the goods in the sth branch, and a quantity index (Q) of all goods.

Although (16) is homogenous of degree zero, there is no compelling reason to impose this constraint on the market demand, as recent studies have shown.[4] Hence, it will be left as a hypothesis to be tested, along with negativity and additivity. In view of these considerations, (16) may be written as

$$(23)\quad \ln q_{si} = a_{si} + b_{si} \ln P + c_{si} \ln P_s + d_{si} \ln P_{si} + e_{si} \ln m.$$

Virtually all studies which have tested some form of the habit formation or adjustment hypothesis have confirmed its existence. For this model, the simple but intuitively appealing partial adjustment model is used, where

$$(24)\quad (q_{si}/g_{si}) = (q^*_{si}/g_{si})^{\Theta_{si}},$$

where g_{si} is the lagged value of q_{si}, q^*_{si} denotes the desired level of q_{si} or (23), and Θ_{si} is the proportion of the desired level which is achieved in any period. Using (23) and (24) gives

$$(25)\quad \ln q_{si} = a_{si}\,\Theta_{si} + b_{si}\,\Theta_{si} \ln P + c_{si}\,\Theta_{si} \ln P_s + d_{si}\,\Theta_{si} \ln p_{si} + e_{si}\,\Theta_{si} \ln m + (1 - \Theta_{si}) \ln g_{si},$$

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[3] It is worth noting that $f_{si}^{M} = 1.0$ for all inverse-demand systems. Hence, all inverse demands can be written in normalized form, or, $z_i = f_i\,(q_1, \ldots, q_n)$ where $z_i = p_i/m$.

[4] See, for example, Deaton; and Green, Pope, and Eales. This result is not surprising in view of the aggregation conditions surrounding the problem. On the aggregation conditions, see Lau.

which is the model to be estimated for the ACS q-dependent system. This empirical formulation differs considerably from its theoretical counterpart, (16). The main difference is the specification of a unique parameter for each variable for each equation. This increased flexibility will be used to test the appropriateness of the S-branch model and to test the theoretical restrictions. The latter tests are

homogeneity:

$$b_{si} + c_{si} + d_{si} + e_{si} = 0 \quad \forall\ si,$$

additivity:

$$\sum_{s=1}^{S} \sum_{i\epsilon s}^{n_s} \bar{w}_{si}\, e_{si} = 1.0,$$

negativity:

$$\bar{w}_{si}\, b_{si} + \bar{W}_{si}\, c_{si} + d_{si} < 0 \quad \forall\ si.$$

Tests for the constancy of σ can be made by determining if individual b_{si} are significantly different from the mean of the b_{si}'s. Similar tests can be made for the constancy of the σ_r's. Homotheticity, ($e_{si}^M = 1.0$), can be tested for each relation in a straightforward way. Analogous tests can be made on the inverse demand equations. The empirical specification for the inverse demand system is

$$(26) \quad \ln p_{si} = f_{si} + h_{si} \ln Q + k_{si} \ln Q_s + n_{si} \ln q_{si} + r_{si} \ln m.$$

Empirical Results

The statistical tests for the ACS system were conducted using annual time-series data covering 1947–79. The individual commodities and their respective groups are listed in table 1. The data on quantities consumed per capita for nonaggregated food items were obtained from various issues of *Food Consumption, Prices, and Expenditures* (USDA). Data on aggregate food categories were obtained by computing divisia indexes of price and quantity from the individual components. The food data were then augmented with U.S. income and product accounts data to include other nondurables and services.

The relations given by (25) and (26) were estimated using nonlinear three-stage least squares. The results for the q-dependent system are given in table 1. Column (1) gives the overall and group budget shares for each good. Columns (2)–(7) give the parameter estimates and their t-ratios (below in parentheses). The reasonably high t-ratios on many of the parameters are evidence that the system has succeeded to some extent in overcoming multicollinearity. The estimates of the habit component, column (7), are in line with the findings of Brown and Heien for food products. Furthermore, these estimates are considerably lower than those found in more aggregative studies, such as Pollak and Wales and Houthakker and Taylor. Hence, it appears that habit, when examined at a disaggregated level, is not as significant as previous studies suggest.

Column (8) gives the degree of homogeneity in prices and income. The t-ratio, below in parentheses, is for the zero-degree homogeneity test for each relation. For all items but four (margarine, bread and cereal, services, and other nondurables) the degree of homogeneity was not significantly different from zero. Column (9) gives the own-price elasticity and forms the basis for the negativity test. The t-ratios indicate that the own-price elasticity is significantly less than zero. In all cases the point estimate of the own-price elasticity is negative, and in nine cases it exceeds twice its standard error. Column (10) gives information regarding the appropriateness of the S-branch specification. The statistic, 1.14, is the overall mean of σ from each regression. Below the estimates are the t-ratios for the test of whether the individual σ's are significantly different from 1.14 (taken as a fixed number). The results indicate that in only three cases is the individual σ significantly different from the system-wide mean. Hence, the assumption of a common elasticity of substitution between goods in different groups cannot be rejected. Column (11) presents similar information regarding tests for the elasticity of substitution within each group. For the protein group, the mean is .75. In one case, eggs, the individual σ_s is significantly different from the group mean. For the fruits and nonfood groups, the assumption of a common elasticity of substitution within groups does not appear to be warranted. Column (12) presents the tests for unitary income elasticity (homotheticity). For the majority of commodities, the tests indicate that homotheticity should be rejected. The budget-share-weighted sum of the income elasticities is .922, which is not significantly different from 1.0 by the two standard errors test. Hence, the assumption of additivity (B.3) cannot be rejected.

Table 1. Empirical Results for q-Dependent ACS System

Group / Commodity	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	w_{si} W_{si}	a_{si}	b_{si}	c_{si}	d_{si}	e_{si}	Θ_{si}	Homogeneity	Negativity	σ (1.14)	σ_s	Homotheticity (t-ratio)
Protein											.75	
Beef	.029	−5.71	−.61	.14	−1.00	1.27	.68	−.20	−.96	.39	1.00	
	.452	(3.04)	(1.61)	(.78)	(5.93)	(5.43)	(5.36)	(.39)	(5.18)	(1.99)	(1.47)	1.17
Pork	.020	1.47	−.48	.84	−.75	.33	1.06	−.06	−.51	.52	.75	
	.296	(1.55)	(2.48)	(11.68)	(13.91)	(2.79)	(18.18)	(.88)	(10.63)	(3.26)	(0.00)	5.58
Chicken	.008	.62	−.08	.78	−.89	.33	.58	.14	−.80	.92	.89	
	.118	(.30)	(.24)	(3.74)	(6.43)	(1.27)	(3.63)	(.84)	(4.92)	(.66)	(1.00)	2.58
Eggs	.010	6.56	−.20	.74	−.36	−.39	.28	−.21	−.26	.80	.36	
	.133	(3.48)	(.52)	(3.50)	(3.05)	(1.66)	(4.29)	(.49)	(2.43)	(.89)	(3.90)	6.04
Spreads											1.634	
Butter	.004	20.34	3.49	.30	−2.13	−2.29	.25	−.63	−1.926	4.49	2.13	
	.645	(1.95)	(1.43)	(.38)	(1.54)	(1.77)	(1.76)	(.35)	(1.10)	(1.37)	(.35)	2.62
Margarine	.002	−3.01	−1.22	2.37	−1.14	.64	.21	−2.36	−.304	−.22	1.14	
	.354	(.48)	(.77)	(1.76)	(2.75)	(.81)	(2.34)	(3.81)	(2.23)	(.86)	(1.21)	.45
Fruits											2.10	
Frozen orange juice	.001	4.94	1.28	.35	−.56	−.28	.18	.79	−.535	2.28	.56	
	.066	(.08)	(.09)	(.03)	(.22)	(.04)	(2.50)	(.06)	(.18)	(.08)	(.22)	.10
Fresh fruits	.010	−13.54	−1.42	4.57	−5.30	1.99	.20	−.16	−3.021	−.42	5.30	
	.503	(1.40)	(1.08)	(3.40)	(3.07)	(1.80)	(3.62)	(.16)	(2.63)	(1.18)	(1.85)	.90
Canned fruits	.008	6.28	1.35	−.36	−.45	−.38	.68	.16	−.589	2.35	.45	
	.431	(3.16)	(3.27)	(.89)	(1.50)	(1.54)	(5.79)	(.87)	(1.36)	(2.95)	(5.50)	2.58
Other food											.72	
Processed vegetables	.007	−3.52	.09	−.28	−.83	.80	.33	−.22	−.856	1.90	.83	
	.097	(1.57)	(.13)	(.86)	(2.84)	(2.75)	(3.61)	(1.0)	(2.98)	(.07)	(.38)	.68
Potatoes	.014	11.36	.99	.64	−.52	−.81	.32	.62	−.392	1.99	.52	
	.176	(2.40)	(.75)	(.51)	(1.18)	(1.38)	(1.80)	(.49)	(.98)	(.64)	(.45)	3.12
Fresh vegetables	.015	2.65	−.42	.56	−.44	.26	.23	−.04	−.347	.58	.43	
	.184	(.97)	(.69)	(1.61)	(1.22)	(.77)	(2.87)	(.40)	(.87)	(.92)	(.78)	2.17
Bread and cereal	.024	8.49	.77	.39	−.43	−.42	.21	.31	−.294	1.77	.43	
	.306	(3.69)	(1.13)	(1.22)	(1.11)	(1.40)	(2.99)	(4.76)	(.95)	(.93)	(.74)	4.73
Milk	.019	9.29	.82	.35	−.64	−.55	.30	−.02	−.539	1.82	.64	
	.236	(9.16)	(2.42)	(1.91)	(2.36)	(3.75)	(3.53)	(.13)	(2.21)	(1.98)	(.30)	3.00
Nonfood											.26	
Other nondurables	.364	−2.69	−.37	−.52	−.50	1.20	1.10	−.19	−.869	.63	.50	
	.442	(10.39)	(2.26)	(4.00)	(12.26)	(38.07)	(29.52)	(3.47)	(14.41)	(3.12)	(5.85)	6.45
Services	.464	−1.00	−1.82	1.02	.02	1.01	.62	.23	−.255	−.82	.02	
	.558	(2.36)	(7.00)	(3.44)	(.30)	(19.50)	(11.64)	(3.07)	(1.59)	(1.06)	(3.63)	.20

Table 2 presents analogous statistics for the ACS system estimated in the p-dependent form of equation (26). Columns (2)–(6) display high t-ratios, evidencing a lack of collinearity. The t-ratios appear generally to be higher for the p-dependent case. This is not surprising since there is less correlation among the q_{si}'s than the p_{si}'s. This lack of correlation is one of the main reasons for estimating demand curves in the p-dependent form. Column (7) presents the t-ratios for the zero degree homogeneity of prices and income test. For p-dependent relations, this condition appears as a unitary elasticity of price with respect to income. In eight cases the t-ratios exceeded 2.0, indicating that this assumption is rejected. This is contrary to the findings for the q-dependent system. Column (8) gives the results of the test for homogeneity of quantities-B.5. In seven cases the t-ratio exceeded two, and for several others it exceeded one. Hence, the hypothesis of minus unitary homogeneity of quantities is rejected.

The test of negativity, column (9), shows general lack of rejection. In twelve cases the t-ratios exceeded 2.0 and were generally quite high. Column (10) presents the tests for the constancy across all commodities of ρ. The overall mean of ρ is .93. In seven cases the individual estimate of ρ is significantly different from the overall mean. Hence, for the p-dependent system the assumption of a common elasticity of substitution is rejected.

Column (11) gives the test statistics for intragroup constancy of ρ_s. Here the results show a general rejection of the notion of a common elasticity of substitution within groups. For the q-dependent system constancy of σ and σ_s generally was not rejected. In the p-dependent case both are rejected. However, two caveats are appropriate. First, as seen from (16), unambiguous estimates of σ and σ_s are not possible. The tests given here used $\hat{\sigma} = b_{si} - 1$ and $\hat{\sigma}_s = d_{si}$. Hence, the estimates of σ and σ_s implied by c_{si} were ignored. The only way to resolve this ambiguity is to impose zero-degree homogeneity and eliminate c_{si}. Then the homogeneity test would not be possible. Similar comments apply to the estimation of ρ and ρ_s. Second, the tests assumed that the overall mean and group means were nonstochastic.

In summary, the above tests revealed five main findings. First, both systems showed a high degree of statistical precision as revealed by the standard errors of the parameter estimates. This precision indicates that the ACS system has been successful to some extent in mitigating the effects of multicollinearity. The main reason for less multicollinearity is the significant reduction in RHS variables made possible by the a priori utility specification. In return for this benefit, the ACS system requires that the a priori assumption of separability and the grouping of commodities be generally appropriate. Second, the maintained hypothesis of negativity is overwhelmingly not rejected in both systems. Third, the maintained hypothesis of homogeneity in prices and income is accepted in the q-dependent system and rejected in the p-dependent one. Similarly, the S-branch notion of constant elasticities of substitution is accepted in the q-dependent system and rejected in the other. Lastly, although the estimates show that habit plays a significant role in food demand, it is not as large as other studies on more aggregate commodities suggest. The assumption of homotheticity also was uniformly rejected.

The elasticity matrix associated with the q-dependent system is given in table 3. The matrix reflects substantial intragroup substitution and quite small intergroup effects. Larger intergroup effects do occur for beef, other nondurables, and services. Large intergroup effects were not excluded a priori and are allowed for through the effect of P. As an empirical matter, these effects were not large. The income elasticities associated with the matrix are given by e_{si}, column (6), table 1. Although not shown here, the flexibility matrix associated with the p-dependent estimates of table 2 was computed. It revealed a pattern similar to the elasticity matrix.

In comparing the above results with those of Brandow and George and King, several points come to mind. First, all three systems show similar structure: large intragroup and small intergroup effects. All three studies rely on the grouping concept, and to some extent the groups are similar. Second, there is considerable similarity in the own-price elasticity. All three studies found the price elasticity for eggs to be near −.30. Similar elasticities were also found for beef, pork, and milk; while those for chicken, butter, and fruits differed considerably. Third, more divergence was found among the income elasticities. For example, George and King and Brandow found beef income elasticities of .29 and .47, respectively. The present study found it to be 1.27. Fourth, the Brandow and George and King studies

Table 2. Empirical Results for p-Dependent ACS System

Group / Commodity'	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
							Homogeneity		Nega-	ρ	
	w_{si} W_{si}	f_{si}	h_{si}	k_{si}	n_{si}	r_{si}	Prices	Quantities	tivity	(+.93)	ρ_s
Protein											.26
Beef	.029	−4.78	.50	−.11	−1.02	.80		−.63	−1.06	−.50	−.70
	.452	(5.35)	(1.74)	(.40)	(11.63)	(9.65)	2.41	(2.04)	(12.47)	(4.52)	(3.50)
Pork	.02	3.35	−.56	−1.25	−.68	1.01		−2.49	−1.066	+.56	.44
	.296	(2.48)	(1.29)	(4.07)	(8.98)	(8.06)	.08	(3.77)	(8.91)	(.58)	(.58)
Chicken	.008	−.78	.46	−1.38	−1.43	.99		2.35	−1.59	−.46	.57
	.118	(.56)	(1.06)	(4.50)	(14.83)	(8.88)	.09	(5.02)	(9.48)	(2.95)	(1.00)
Eggs	.010	6.86	−1.09	−1.52	−.16	.79		−2.79	−.38	+1.09	.71
	.133	(2.61)	(1.86)	(3.61)	(.54)	(4.65)	1.23	(2.91)	(3.80)	(.52)	(1.07)
Spreads											−.13
Butter	.040	5.09	−1.17	−.92	.09	.54		−2.00	−.51	+1.17	.11
	.645	(3.12)	(3.42)	(3.18)	(.47)	(4.81)	4.18	(1.66)	(4.86)	(1.05)	(.83)
Margarine	.002	5.45	−2.28	−.45	−.93	1.49		−3.66	−1.09	+2.28	−.36
	.354	(3.16)	(5.79)	(3.25)	(9.31)	(11.34)	3.76	(5.52)	(11.60)	(3.68)	(1.64)
Fruits											−.19
Frozen orange juice	.001	10.89	−2.20	−1.24	−.02	1.03		−3.46	−.10	+2.20	.43
	.066	(2.40)	(2.77)	(2.30)	(.65)	(3.66)	.11	(1.63)	(2.85)	(1.74)	(1.15)
Fresh fruit	.010	.17	−1.14	−.46	−.12	1.06		1.72	−.36	+1.14	−.35
	.503	(.16)	(6.17)	(5.31)	(2.35)	(17.46)	1.00	(1.37)	(6.21)	(1.79)	(1.84)
Canned fruit	.008	5.74	−2.07	−.16	−.46	1.19		2.69	−.55	+2.07	−.65
	.431	(5.11)	(9.06)	(1.12)	(4.20)	(14.86)	2.38	(3.93)	(5.83)	(5.53)	(3.28)
Other food											−1.96
Processed vegetables	.007	−8.54	−.93	1.41	.12	.89		.60	.01	+.93	−2.22
	.097	(5.82)	(5.55)	(6.28)	(1.14)	(20.13)	2.50	(1.21)	(.56)	(.71)	(1.18)
Potatoes	.014	−7.69	−2.01	4.56	−2.62	1.20		−.07	−1.85	+2.01	−5.37
	.176	(1.13)	(2.93)	(3.85)	(5.16)	(5.15)	.86	(.06)	(6.93)	(1.75)	(2.89)
Fresh vegetables	.015	−4.37	−.58	.27	−.26	.90		−.57	−.22	+.58	−1.08
	.184	(2.42)	(3.62)	(.80)	(1.34)	(17.41)	1.92	(1.47)	(2.35)	(1.44)	(2.58)
Bread and cereal	.024	5.93	−1.83	−.48	−.46	1.25		−2.77	−.65	+1.83	−.33
	.306	(3.32)	(10.54)	(1.18)	(2.33)	(21.48)	4.31	(2.39)	(4.21)	(5.86)	(3.98)
Milk	.019	1.37	−1.38	−.03	−.27	.94		−1.68	−.30	+1.38	−.78
	.236	(.54)	(7.10)	(.11)	(.90)	(16.50)	1.05	(1.10)	(2.61)	(2.94)	(4.37)
Nonfood											1.48
Other nondurables	.364	1.34	−1.70	.37	−.36	1.16		−1.59	−.72	+1.70	−1.18
	.442	(1.30)	(1.17)	(.30)	(1.37)	(18.37)	2.54	(.18)	(2.11)	(.61)	(2.16)
Services	.464	−9.09	4.97	−4.94	.99	.49		1.02	.54	−4.97	4.13
	.558	(4.51)	(1.74)	(2.01)	(2.22)	(4.15)	4.32	(.37)	(3.21)	(2.02)	(1.08)

Table 3. Elasticity Matrix of q-Dependent ACS System

	Beef	Pork	Chicken	Eggs	Butter	Margarine	Orange Juice	Fresh Fruit	Processed Fruit	Processed Vegetables	Potatoes	Fresh Vegetables	Bread	Milk	Other Nondurables	Services	Income
Beef	**−0.956**	**0.030**	**0.012**	**0.013**	−0.002	−0.001	−0.001	−0.006	−0.005	−0.005	−0.009	−0.009	−0.015	−0.012	−0.221	−0.282	1.27
Pork	**0.364**	**−0.511**	**0.095**	**0.107**	−0.002	−0.001	−0.001	−0.005	−0.004	−0.004	−0.007	−0.007	−0.012	−0.009	−0.177	−0.225	.33
Chicken	**0.350**	**0.299**	**−0.797**	**0.104**	−0.000	−0.000	−0.000	−0.001	−0.001	−0.001	−0.001	−0.001	−0.002	−0.002	−0.031	−0.039	.33
Eggs	**0.330**	**0.216**	**0.086**	**−0.263**	−0.001	−0.000	−0.000	−0.002	−0.002	−0.002	−0.003	−0.003	−0.005	−0.004	−0.074	−0.095	−.39
Butter	0.102	0.069	−0.027	0.033	**−1.926**	**0.112**	0.004	0.035	0.029	0.026	0.050	0.051	0.085	0.067	1.275	1.624	−2.29
Margarine	−0.036	−0.024	0.010	−0.012	**1.526**	**−0.304**	−0.001	−0.012	−0.010	−0.009	−0.018	−0.018	−0.030	−0.023	−0.447	−0.569	.64
Orange juice	0.037	0.025	−0.010	0.012	0.005	0.002	**−0.535**	**0.189**	**0.162**	0.010	0.018	0.018	−0.031	0.024	0.465	0.593	−.28
Fresh fruit	−0.042	−0.028	0.011	−0.013	−0.005	−0.002	**0.303**	**−3.021**	**1.956**	−0.011	−0.028	−0.021	−0.035	−0.027	−0.519	−0.662	1.99
Processed fruit	0.039	0.027	0.011	0.013	0.005	0.002	**−0.022**	**−0.167**	**−0.589**	0.010	0.019	0.020	0.033	0.026	0.493	0.629	−.38
Processed vegetables	0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.001	0.001	**−0.856**	**−0.049**	**−0.051**	**−0.084**	**−0.065**	0.031	0.040	.80
Potatoes	0.029	0.020	0.008	0.009	0.004	0.002	0.001	0.010	−0.008	**0.069**	**−0.392**	**0.132**	**0.219**	**0.170**	0.362	0.461	−.81
Fresh vegetables	−0.012	−0.008	0.003	−0.004	−0.002	−0.001	−0.001	−0.004	0.004	**0.051**	**0.093**	**−0.347**	**0.162**	**0.125**	−0.154	−0.197	.26
Bread	0.022	0.015	0.006	0.007	0.003	0.001	0.001	0.008	0.006	**0.043**	**0.079**	**0.083**	**−0.294**	**0.106**	0.281	0.358	−.42
Milk	0.024	0.016	−0.006	0.008	0.003	0.001	0.001	0.008	0.007	**0.040**	**0.073**	**0.076**	**0.126**	**−0.539**	0.300	0.382	−.55
Other nondurables	−0.011	−0.007	−0.003	−0.004	−0.001	−0.001	−0.000	−0.004	−0.003	−0.003	−0.005	−0.005	−0.009	−0.007	**−0.869**	**−0.465**	1.20
Services	−0.053	−0.036	−0.014	−0.017	−0.007	−0.003	−0.002	−0.018	−0.015	−0.014	−0.026	−0.026	−0.044	−0.035	**−0.215**	**−0.255**	1.01

imposed the various theoretical restrictions on the elasticity matrix. The present study tested the assumptions, and the matrix does not satisfy these restrictions exactly. Fifth, in the present study all price and income effects are estimated in a one-step regression (nonlinear three-stage least squares). In the other studies, information on elasticities obtained from various single equation regressions was combined with the Frisch approach to compute elasticities for goods on whom no cross-price information was available. Last, the present study includes a dynamic specification for the demand model which was not present in the previous studies. Hence, it is possible to distinguish between short- and long-run demand.

Summary

The results of this paper may be summarized as follows. First, a new demand model, the ACS system, has been introduced. This system is designed to mitigate the effects of multicollinearity and facilitate the measurement of cross-price effects. It has the feature of being tractable in terms of a parent utility function. The model is applicable to single-equation situations as well as complete systems. Second, the theory of inverse demand equations has been presented. Third, a complete set of demand relations for fourteen food items was estimated in both the quantity- and price-dependent form. The model permits tests on the theoretical restrictions of homogeneity, negativity, and additivity. All three assumptions could not be rejected for the p-dependent systems. Homogeneity was rejected in the p-dependent system. Estimates of the role of habit showed it to be significant, but less than suggested by studies using more aggregate data.

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Appendix

Elasticity-Flexibility Relations

A. Elasticities and Flexibilities for ACS System

A.1 $e_{si,rj}{}^{P} = (\sigma - 1)w_{rj}$

A.2 $e_{si,sj}{}^{P} = (\sigma - 1)w_{sj} + (\sigma_s - \sigma)W_{sj}$

A.3 $e_{si,si}{}^{P} = (\sigma - 1)w_{si} + (\sigma_s - \sigma)W_{si} - \sigma_s$

A.4 $e_{si}{}^{M} = 1.0$

A.5 $w_{rj} = p_{rj}\, q_{rj}/m$

A.6 $W_{rj} = p_{rj}\, q_{rj}/m_r$

A.7 $m_r = \sum_{j\epsilon r}^{n_r} p_{rj}\, q_{rj}$

A.8 $f_{si,rj}{}^{Q} = -\rho\ w_{rj}$

A.9 $f_{si,sj}{}^{Q} = -\rho\ w_{sj} + (\rho - \rho_s)W_{sj}$

A.10 $f_{si,si}{}^{Q} = -\rho\ w_{si} + (\rho - \rho_s)W_{si} + (\rho_s - 1)$

A.11 $f_{si}{}^{M} = 1.0$

B. Theoretical Restrictions on Complete Demand Systems
Regular:

B.1 Homogeneity: $\sum_{r=1}^{S} \sum_{j\epsilon r}^{n_r} e_{si,rj} = -e_{si}{}^{M} \quad \forall\ si$

B.2 Symmetry: $e_{si,rj}{}^{P}/w_{rj} + e_{rj}{}^{M} = e_{rj}{}^{M} + e_{rj,si}{}^{P}/w_{si}$

B.3 Additivity: $\sum_{r=1}^{S} \sum_{j\epsilon r}^{n_r} w_{rj}\, e_{rj}{}^{M} = 1.0$

B.4 Negativity: $e_{si}{}^{P} < 0$

Inverse:

B.5 Homogeneity: $\sum_{r=1}^{S} \sum_{j\epsilon r}^{n_r} f_{si,rj}{}^{Q} = -1.0$

B.6 Symmetry: $f_{si,rj}{}^{Q} - w_{rj} = f_{rj,si}{}^{Q} - w_{si}$

B.7 Additivity: $\sum_{r=1}^{S} \sum_{j\epsilon r}^{n_r} w_{rj} = 1.0$

B.8 Negativity: $f_{si}{}^{Q} < 0.$

Inventory Adjustment and Dynamic Winery Behavior

Michael K. Wohlgenant

This paper develops a dynamic model of processor behavior which is applied to the California wine industry. Price, production, and input demand functions are derived from an optimal control model which takes into account inventory growth from aging and the linkage between product inventories and input purchases. An important feature of the model is that expected future market conditions and beginning inventories influence current behavior through changes in the inventory shadow price. The empirical results generally conform to the theoretical specification and emphasize the role of demand expectations on winery behavior.

Key words: inventory theory, optimal control theory, processor behavior, wine.

This paper presents a dynamic model of processor behavior which is applied to the California wine industry. Although the model was developed primarily for estimating dynamic behavior in the wine industry, it also serves as a more general framework for specifying behavioral relationships in agricultural processing. The general approach to modeling dynamic processor behavior draws on recent contributions by Hay and, in particular, Maccini (1976, 1977). In this approach, the industry behavioral equations are derived from a dynamic optimization model of a representative firm. A key feature is that the firm is viewed as a short-run monopolist setting product price, the rate of output, and inventories to maximize expected present value of future net revenue.

This approach has the advantage of providing a strong theoretical underpinning of various factors (product demand expectations, input price expectations, beginning inventory, etc.) which influence the maximizing process. The model developed here considers explicitly the linkage between product inventory adjustment and raw material input purchases. Factor input choices are linked to the rate of output through the production function. Therefore, factors which influence output price, production, and inventory behavior also would be expected to influence the demand for purchased raw materials.

Before presenting the development of the dynamic model in detail, a few features of the wine industry are sketched briefly to indicate why various aspects of the dynamic model are relevant to modeling winery behavior. In 1972, the four-firm concentration ratio in the wine industry was approximately 0.5, according to the *Census of Manufacturers* (U.S. Dep. of Commerce). Considerable product heterogeneity exists among the various brands of wine with brand loyalty an important characteristic of demand (Folwell and Baritelle). The four major wine products are table wine, dessert wine, sparkling wine, and brandy. Table and dessert wine are the two most important products, accounting for approximately 90% of all wine shipments from California (Wine Institute, *Wine Industry Statistical Report*). Wine is a storable product, and some wines can be aged for quality enhancement. Detailed information on individual firm stocks is not available. However, industry inventory-shipment ratios of each major product, except sparkling wine, historically have exceeded one, suggesting considerable storage from one crop year to the next. Grapes purchased for crushing are reported (California Crop and Livestock Reporting Service) by type and variety: raisin grapes (five varieties, of which Thompson Seedless was 487 thousand tons of total crushings of all grapes of 2.0 million tons in 1978); table grapes (22 varieties of 142 thousand tons) and wine grapes (32 white varieties of 472 thousand tons and 45 black varieties of 883

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thousand tons). Grapes are blended to produce desired qualities. A detailed linking of varieties to wines produced would be a study in itself. However; the three grape types are distinct enough in price terms to allow an aggregate analysis.

With this brief background, the paper presents a theoretical model for an individual firm and empirical results from the aggregate industry model applied to the wine industry.

Dynamic Model of an Individual Processor

Consider a representative processor in an industry, such as wine, engaged in production, storage, and sale of a single commodity. At the beginning of each time period, the firm holds a given stock of the commodity and selects time paths of its decision variables (rate of output, output price, and quantities of factor inputs) which maximize the expected present value of future net revenue. The basic components of this model are a net revenue function, a production function linking factor input quantities to the rate of output, and an inventory accumulation equation to describe how the capital stock changes as decisions are made and the state of the system changes. The model is formulated in continuous rather than discrete time to facilitate derivation of the decision rules. In the empirical analysis, the behavioral relationships are then expressed in discrete time units.

Behavioral Assumptions

A distinguishing characteristic of wine manufacturing is quality enhancement from length of time in storage (i.e., aging). Quality changes from aging could be directly introduced into the net revenue function. However, the approach taken here is to incorporate them into the specification of the inventory accumulation equation as done by Rausser and Hochman (p. 46). Let t denote the time at which the firm implements its decisions, and let τ refer to a point in time in the firm's planning horizon, where $t \leq \tau < \infty$. Let $k(\tau)$ refer to the firm's expected stock of a given wine vintage at τ (i.e., wine of a given age), $q(\tau)$ denote planned production, and $s(\tau)$ denote the expected quantity of wine sold. With the proportionate rate of quality change assumed independent of the stock size, the stock accumulation equation is

$$(1)\quad \dot{k}(\tau) = \frac{dk(\tau)}{d\tau} = q(\tau) - s(\tau) + \mu(\tau,t)k(\tau);\ k(t) = k_t,\ \mu(t,t) = \mu_t,$$

where $\mu(\tau,t)$ is the proportionate rate of quality change from length of time in storage. This equation states that the time rate of change in the wine stock at τ equals the difference between the amount produced and sold at τ plus the rate of appreciation in the stock from holding it in inventory an additional time period. This specification indicates that at the end of a particular time period, during which quality is increasing at a constant proportional rate, μ, one gallon of old wine is equal to $1 + \mu$ gallons of new wine. In general, the proportionate rate of quality change is not constant but is a function of the length of time the wine is aged. Thus, the quality parameter is a function of both t and τ.

Sometimes we may assume that the firm is a price taker in the product market. Here we consider the more general specification in which the firm is assumed to behave as a short-run monopolist. The firm's perceived demand function is

$$(2)\quad s(\tau) = n[p(\tau),\ p_a^e(\tau),\ s_a^e(\tau)] \qquad n_p < 0,\ n_{p_a} > 0,\ n_{s_a} > 0,$$

where $p(\tau)$ is the price the individual firm charges for its commodity, $p_a^e(\tau)$ is the firm's expectation of the average industry market price at τ (assumed not to be affected by the individual firm's price), and $s_a^e(\tau)$ is the firm's expectation of market demand at τ (expected industry shipments). This demand function suggests that the firm may influence its market share by varying its price relative to the average industry price (Maccini 1976, pp. 189–90).

Expected net revenue is

$$(3)\quad \Pi(\tau) = p(\tau)s(\tau) - \sum_{i=1}^{m} r_i^e(\tau)x_i(\tau) - g[s(\tau),\ k(\tau)],$$

where $r_i^e(\tau)$ is the firm's expected price of the ith input at τ, $x_i(\tau)$ is the quantity of the ith input purchased at τ, and $g(\tau)$ denotes expected inventory costs. (Selling costs are not included in the theoretical analysis but are in the empirical model.)

The sales rate and commodity inventory appear in the inventory cost function to reflect direct storage costs and savings (convenience benefits) from holding inventory. Direct storage costs include costs of placing the commodity in storage, maintaining it while in storage, insuring it, etc. Savings accrue to processors from holding "pipeline" stocks. In particular, added inventory coverage (shown by the inventory-shipment ratio) reduces the likelihood of stockouts from unanticipated demand fluctuations. It also yields savings from reduced transaction costs and added flexibility in production and distribution. Overall, storage costs would be expected first to fall as cost savings from inventory coverage occur and then to rise as direct holding costs become dominant.

The production function is

$$(4) \qquad q(\tau) = f[x(\tau)],$$

where $x(\tau) = [x_1(\tau), x_2(\tau), \ldots, x_m(\tau)]'$ and $f(\cdot)$ is assumed to be twice differentiable with positive and diminishing marginal products.

Net Revenue Maximization and Optimal Inventory Accumulation

The firm is assumed to select the time paths of its decisions variables so as to maximize the expected present value of future net revenue. This general problem is mathematically intractable; but with first-order certainty equivalence, it reduces to maximizing the present value of future net revenue with each stochastic variable being replaced by its conditional expectation (Nerlove or Malinvaud). Under this specification the firm is assumed to maximize

$$(5) \qquad \int_t^\infty \Pi(\tau)e^{-\rho(\tau-t)}d\tau,$$

subject to (1), (2), and (4). $\Pi(\tau)$ is defined in (3) and ρ is the instantaneous interest rate. All prices are in real, rather than nominal, values.

To solve the optimization problem, notice that for a given planned rate of output, conditional factor demand functions may be obtained by simply minimizing input costs for each time period subject to the production function in (4). These demand functions are[1]

$$(6) \quad x_i(\tau) = x_{ci}[r^e(\tau), q(\tau)], \; i = 1, 2, \ldots, m,$$

where

$$r^e(\tau) = [r_1^e(\tau), r_2^e(\tau), \ldots, r_m^e(\tau)]',$$
$$\partial x_{ci}/\partial r_i < 0, \text{ and } \partial x_{ci}/\partial q > 0.$$

To further simplify derivation of the decision rules, expected shipments, $s(\tau)$, are selected as a control variable rather than output price. This means that the firm's inverse demand function must be obtained from (2) as

$$(7) \qquad p(\tau) = h[s(\tau), p_a^e(\tau), s_a^e(\tau)],$$
$$h_s < 0, \; h_{p_a} > 0, \; h_{s_a} > 0.$$

Upon substituting (6) and (7) into (3) and the resulting expression into (5), the firm's maximization problem becomes

$$(8) \quad \int_t^\infty \{h[s(\tau), p_a^e(\tau), s_a^e(\tau)]s(\tau) - c[r^e(\tau), q(\tau)] - g[s(\tau), k(\tau)]\}e^{-\rho(\tau-t)}d\tau,$$

subject to the inventory equation in (1), where

$$c[r^e(\tau), q(\tau)] = \sum_{i=1}^{m} r_i^e(\tau)x_{ci}(\tau).$$

The First-Period Decision Rules

To facilitate derivation of the decision rules, assume that the firm takes p_a^e, s_a^e, r^e, and μ as constant over its planning horizon. Hence,

$$p_a^e(\tau) = p_a^e(t) = p_{at}^e,$$
$$s_a^e(\tau) = s_a^e(t) = s_{at}^e,$$
$$r_i^e(\tau) = r_i^e(t) = r_{it}^e, \text{ and}$$
$$\mu(\tau,t) = \mu(t,t) = \mu_t.$$

These assumptions are logical if the expected variables are the expected "normal" levels of these variables (Nerlove, Grether, Carvalho, chap. 13). The quality change parameter, μ, may be viewed as constant over the firm's planning horizon if the initial position of the firm at t is relatively close to its equilibrium position.

Furthermore, to obtain determinate coefficient signs of the decision rules, the Hamiltonian function (9) is assumed to be concave in q, s, and k; and

$$(12) \qquad g_{sk} = g_{ks} < 0,$$
$$h_{sp_a} > 0$$
$$h_{ss_a} > 0, \text{ and}$$
$$c_{qr_i} > 0.$$

With these assumptions, the equations in (10) may be reduced to an autonomous system of first-order differential equations in λ and k and solved for optimal policies at t. The solution for the shadow price of inventory at t is

$$(13) \qquad \lambda_t = \lambda(p_{at}^e, s_{at}^e, r_t^e, \mu_t, \rho_t, k_t),$$

where

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[1] This step is valid provided the winery is a price taker in the markets for all its factor inputs, including grapes, and incurs no adjustment costs.

$\lambda_{p_a} > 0, \lambda_{s_a} > 0, \lambda_{r_i} > 0, \lambda_\mu > 0, \lambda_\rho < 0, \lambda_k < 0.$

This specification indicates intuitively that an increase in expected demand (through p_a^e or s_a^e), an increase in the rate of quality change, a decrease in the interest rate, and a decrease in the initial inventory level would increase the shadow price of inventory. The marginal effect of a change in r_i^e on λ is that an increase in the expected future price of the ith input gives the firm an incentive to expand production and increase inventories at time t. This is because the ith input is now less expensive relative to the future.

The Hamiltonian corresponding to this problem is

$$(9)\quad \begin{aligned} H(\tau) = e^{-\rho(\tau-t)}\{&h[s(\tau), p_a^e(\tau), s_a^e(\tau)]s(\tau) \\ &- c[r^e(\tau), q(\tau)] - g[s(\tau), k(\tau)] \\ &+ \lambda(\tau)[q(\tau) - s(\tau) + \mu(\tau,t)k(\tau)]\}, \end{aligned}$$

where $\lambda(\tau)$ is the current-value shadow price of inventory. Assume an interior maximum exists and let subscripts denote partial derivatives. Then, as shown by Arrow and Kurz, the necessary conditions for maximization of $H(\tau)$ include

$$(10a)\quad -c_q(r^e,q) + \lambda = 0,$$

$$(10b)\quad h(s, p_a^e, s_a^e) + h_s(s, p_a^e, s_a^e)s - g_s(s,k) - \lambda = 0,$$

$$(10c)\quad -g_k(s,k) + \mu\lambda = \rho\lambda - \dot{\lambda},$$

$$(10d)\quad q(\tau) - s(\tau) + \mu(\tau,t)k(\tau) = \dot{k}(\tau),\ k(t) = k_t, \text{ and}$$

$$(10e)\quad \lim_{\tau\to\infty} e^{-\rho(\tau-t)}\lambda(\tau) = 0.$$

Equation (10a) states that marginal production costs must equal marginal returns from an increment in the rate of output, with marginal returns just equal to the shadow price of inventory. Condition (10b) indicates that the firm should equate marginal returns from an increment in sales with marginal costs of an increment in sales. Marginal returns, in this case, equal marginal revenue from quantity sold at τ, while marginal costs equal the sum of marginal storage costs from an increment in sales plus the shadow price of inventory.

Equation (10c) is the adjoint condition illustrating the factors the firm implicitly considers in inventory accumulation, including quality enhancement. Rearrange (10c) as

$$(10f)\quad \dot{\lambda} + \mu\lambda = \rho\lambda + g_k(s,k).$$

Since λ is the current-value shadow price of inventory of a given wine vintage, it represents the capital value of storing a gallon of wine of given quality at time τ. Marginal returns from storing an additional gallon consist of the capital value increment with given quality ($\dot{\lambda}$) and the capital value increment due to quality enhancement from aging, ($\mu\lambda$). Equation (10f) shows that the marginal returns must equal the marginal costs of adding inventory, with marginal costs equaling the sum of interest and marginal inventory holding costs. Notice also that (10f) indicates that the rate of return from storing wine will be greater (and the stock size larger) (a) the larger the increment in expected marginal net revenue from sale of the commodity with given quality, (b) the larger the proportionate increase in product quality from storage, and (c) the lower the marginal costs of adding inventory.

With a solution for the inventory shadow price, the decision rules regarding p_t and q_t are straightforward. Solve equations (7), (10a), (10b) and (13) simultaneously to obtain

$$(14)\quad p_t = p(p_{at}^e, s_{at}^e, r_t^e, \mu_t, \rho_t, k_t),$$

where

$$\begin{aligned} p_{p_a} &= h_s[\lambda_{p_a} - (h_{p_a} + h_{sp_a}s)]/\Delta + h_{p_a} \gtreqless 0, \\ p_{s_a} &= h_s[\lambda_{s_a} - (h_{s_a} + h_{ss_a}s)]/\Delta + h_{s_a} \gtreqless 0, \\ p_{r_i} &= h_s\lambda_{r_i}/\Delta > 0, \\ p_\mu &= h_s\lambda_\mu/\Delta > 0, \\ p_\rho &= h_s\lambda_\rho/\Delta < 0, \\ p_k &= h_s(\lambda_k + g_{sk})/\Delta < 0, \text{ and} \\ \Delta &= (h_{ss}s + 2h_s - g_{ss}) < 0; \end{aligned}$$

$$(15)\quad q_t = q(p_{at}^e, s_{at}^e, r_t^e, \mu_t, \rho_t, k_t),$$

where

$$\begin{aligned} q_{p_a} &= \lambda_{p_a}/c_{qq} > 0, \\ q_{s_a} &= \lambda_{s_a}/c_{qq} > 0, \\ q_{r_i} &= (\lambda_{r_i} - c_{qr_i})/c_{qq} \lesseqgtr 0, \\ q_\mu &= \lambda_\mu/c_{qq} > 0, \\ q_\rho &= \lambda_\rho/c_{qq} < 0, \text{ and} \\ q_k &= \lambda_k/c_{qq} < 0. \end{aligned}$$

The sign restrictions on Δ and c_{qq} follow from the concavity of the Hamiltonian function, (9). The remaining sign restrictions are derived from (12) and (13).

With a few exceptions, the expected signs of equations (14) and (15) are intuitively plausible. An increase in the expected ith input price, an increase in the rate of quality change, a decrease in the interest rate, and a decrease in the beginning inventory level all lead the firm to increase its output price. The effect of an increase in expected demand (through p_a^e

or s_a^e) on p is indeterminate because it also encourages the firm to lower its price and increase its sales in the current period. This effect, however, is likely small, and it seems plausible to expect that $p_{s_a} > 0$.

With the exception of a change in r_i, the expected coefficient signs of the production equation (15) are the same as the price equation (14). The marginal effect of an increase in the expected ith input price on production is indeterminate because the firm has in incentive to substitute current purchases for future purchases if r_i is expected to increase. It seems plausible to expect that the current period effect will dominate the effect from future price changes. Thus, we expect that $q_{r_i} < 0$.

Since input choices are linked to the planned rate of output through (6), demand functions which include the scale effect may be obtained by substituting (15) into (6). These equations have the form:

$$(16) \quad x_{it} = x_i(p_{at}^e, s_{at}^e, r_t^e, \mu_t, \rho_t, k_t),$$

where

$$\begin{aligned}
\partial x_i/\partial p_a &= (\partial x_{ci}/\partial q)(\partial q/\partial p_a) > 0, \\
\partial x_i/\partial s_a &= (\partial x_{ci}/\partial q)(\partial q/\partial s_a) > 0, \\
\partial x_i/\partial r_i &= \partial x_{ci}/\partial r_i + (\partial x_{ci}/\partial q)(\partial q/\partial r_i) < 0, \\
\partial x_i/\partial r_j &= \partial x_{ci}/\partial r_j + (\partial x_{ci}/\partial q)(\partial q/\partial r_j) \gtreqless 0, \\
& \qquad j \neq i, \\
\partial x_i/\partial \mu &= (\partial x_{ci}/\partial q)(\partial q/\partial \mu) > 0, \\
\partial x_i/\partial \rho &= (\partial x_{ci}/\partial q)(\partial q/\partial \rho) < 0, \text{ and} \\
\partial x_i/\partial k &= (\partial x_{ci}/\partial q)(\partial q/\partial k) < 0.
\end{aligned}$$

Observe that the partial derivatives with respect to p_a, s_a, μ, ρ, and k have the same signs as with the production equation (15). This is because their effects enter only through the scale effect. As expected, the own-price effect is negative. However, the effect of a change in r_j on demand for x_i is indeterminate because of possible offsetting scale effects. Observe that if the production function reflects a fixed proportions technology, equations (15) and (16) are equal except for the fixed input-output coefficients. The more general specification is used to account for substitution between grape varieties and marketing inputs in wine manufacturing.

To summarize, equations (14)–(16) indicate that the decision variables of the individual firm are jointly influenced by factors affecting inventory investment. This is because each decision variable is influenced by changes in the shadow price of inventory which, in turn, is affected by changes in expected demand and cost conditions, and the initial inventory level. This model precisely specifies the factors that one would expect to influence price, output, input purchases, and (implicitly) inventory adjustment.

Econometric Analysis of Winery Behavior

The model's qualitative properties, equations (14)–(16), are useful for industry analysis where multiple products, expectations, and possible aggregation errors are present. This section discusses the modifications of the firm model required for the industry analysis and presents econometric results for winery behavior.

The Industry Model

The multiple product case can be reconciled with the single-product model if the underlying production structure is nonjoint in its inputs (Lau, p. 287) or if each firm specializes in a single product. In either case, each price and production equation refers to a specific commodity. Each raw product demand function refers to the amount of each input used in each final product. This creates a slight problem in formulating grape demand functions because data are not available on the proportion of each grape type used in each wine product. Consequently, only three grape demand equations are estimated (wine, table, and raisin-type grapes). Each demand function is expressed as a function of beginning inventories, expected industry shipments, and expected prices of all wine produced from a given grape type. Because this specification contains many parameters to estimate, expected wine shipments and beginning inventories were each replaced by sum aggregates and the separate wine prices were aggregated into an index, whose weights are the proportions of each product in total shipments.[2]

Because data for sparkling wine and brandy are not available, their price and production equations were not estimated. The price index used in the grape demand equations consists only of table and dessert wine prices. Finally, because of incomplete manufacturing cost data, a cost index was constructed to reflect changes in processing and marketing prices over time. It was developed from industry sample cost data and published price changes for important components.[3]

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[2] The weights are 0.41 for table wine and 0.59 for dessert wine, the 1963 estimated relative importance of each reported in *Wholesale Prices and Price Indexes* (U.S. Department of Labor).

Another aggregation problem concerns how changes in the age distribution of stocks affect winery behavior. Recall that the individual firm decision rules refer to a given wine vintage. Therefore, aggregation over firms and commodities will produce industry behavioral equations which depend upon the age distribution of the wine stock at time t. Furthermore, the quality change parameter (μ) will be influenced by changes in the inventory age distribution. Detailed information on the age composition of wine is not available. Therefore, it was not possible to account for this in the econometric analysis. This is probably insignificant since most of the commercial wine produced in California historically has been of standard or nonpremium quality. Also, changes in the quality of wine sold should be reflected in wine prices, although little information is available on the composition of the data used in the price indexes.

With the above limitations in mind, the industry model is specified as

$$(17)\quad X_{it} = \alpha_{0i} + \alpha_{1i}R_{wgt}{}^{e} + \alpha_{2i}R_{tgt}{}^{e} + \alpha_{3i}R_{rgt}{}^{e} + \alpha_{4i}C_t{}^{e} + \alpha_{5i}P_t{}^{e} + \alpha_{6i}S_t{}^{e} + \alpha_{7i}K_t + \alpha_{8i}T + U_{it}{}^{x},$$

$$(18)\quad Q_{jt} = \beta_{0j} + \beta_{1j}R_{wgt}{}^{e} + \beta_{2j}R_{tgt}{}^{e} + \beta_{3j}R_{rgt}{}^{e} + \beta_{4j}C_t{}^{e} + \beta_{5j}P_{jt}{}^{e} + \beta_{6j}S_{jt}{}^{e} + \beta_{7j}K_{jt} + \beta_{8j}T + U_{jt}{}^{q},$$

$$(19)\quad P_{jt} = \gamma_{0j} + \gamma_{1j}R_{wgt}{}^{e} + \gamma_{2j}R_{tgt}{}^{e} + \gamma_{3j}R_{rgt}{}^{e} + \gamma_{4j}C_t{}^{e} + \gamma_{5j}P_{jt}{}^{e} + \gamma_{6j}S_{jt}{}^{e} + \gamma_{7j}K_{jt} + \gamma_{8j}T + U_{jt}{}^{p}, \text{ and}$$

$$(20)\quad K_{jt+1} = K_{jt} + Q_{jt} - S_{jt},$$

where $i = wg, tg, rg$ (wine, table, and raisin grapes, respectively) and $j = tw, dw$ (table and dessert wine, respectively). Capital letters now denote industry aggregates. $C_t{}^e$ is an index of expected normal marketing prices, $P_t{}^e$ is an index of expected normal wine prices, and $S_t{}^e$ is the expected normal level of all wine shipments. $U_{it}{}^x$, $U_{jt}{}^q$, and $U_{jt}{}^p$ are random disturbance terms. The trend variable, T, is included to account for trend effects of omitted variables, such as changes in processing and storage capacity and quality changes not reflected in wine prices or inventories. Equation (20) is an identity which equates ending inventory with beginning inventory plus production minus shipments. A proxy for the expected real rate of interest was initially included but dropped because its effect was insignificant.

Specification of the Expected Variables

The industry behavioral equations in (17)–(19) contain a number of expected variables which must be related to observable magnitudes. Expected input prices are assumed to be a function of their current and lagged values. Expected wine prices and wine shipments are assumed to be a function only of their lagged values. Decisions are made prior to the 1 July crushing season. Input prices are generally known at that time but little information is available on competitors' wine prices and industry shipments for the current year. While wine prices at harvest time are a function only of predetermined variables, the average yearly price could be a function of shipments in year t, suggesting prices might be jointly determined with wine demand. However, an analysis of monthly price changes indicated that the major changes occurred at or shortly after harvest. Thus, this specification seems logical for the sample period.

The lag length for each expected variable was determined by a procedure proposed recently by Nerlove, Grether, and Carvalho (chap. 13). Specifically, each expected variable was assumed to follow a univariate autoregressive - integrated - moving - average (ARIMA) process. Each series was analyzed with time-series techniques to determine the appropriate lag. This approach is called "quasi-rational expectations" because it is generally consistent with Muth's rational expectations hypothesis.

The results of the time-series analysis (which can be obtained from the author) indicated that current year values may be substituted for the input price expectations; one-year lagged values may be substituted for expected wine prices and dessert wine shipments; and the lagged values for years $t - 1$ and $t - 2$ may be substituted for expected table wine shipments and all wine shipments. In general, this procedure will only indicate how many lagged values of the expected variables should be included in the estimating

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[3] The index used is

$$C = 0.40\ W + 0.60\ IBC,$$

where W is an index of wages paid in the wine industry (U.S. Department of Commerce, *Annual Survey of Manufacturers*), and IBC is an index of wholesale prices for glass containers (U.S. Department of Labor, *Wholesale Prices and Price Indexes*, SIC 1380).

equation. This is because the expected variables correspond to normal or long-run expectations, which may be viewed as weighted averages of future one-period expectations. In this particular application, however, the weights of the lag distributions sum to unity because each series modeled was of the type

$$(1 - \theta L)\Delta Z_t = \epsilon_t, |\theta| < 1,$$

where L is the lag operator, Δ is the first-difference operator, and ϵ_t is a random variable with a covariance-stationary process (Nerlove, Grether, Carvalho, p. 325). The sum of the distributed lag coefficients may be interpreted as the marginal effect of the expected normal variable in the econometric equation being estimated.

Data and Estimation Procedure

The equations were fitted with annual crop year data for the period 1951–74. Quantity data for table wine (which also includes natural wines less than 12% alcohol) and dessert wine (which also includes vermouth and natural wines over 12% alcohol) are the amounts produced and shipped from California into U.S. markets. Because other states' sales were a relatively constant and small proportion of all shipments over the sample period, they were not included. The sample period was not extended beyond 1974 because the table wine price series excludes white table wine, which has become a large proportion of all table wine since then.

The grape demand equations were estimated in price dependent form. Grape supplies are virtually predetermined in the short run because production is constrained by past plantings, and grapes are a perennial crop. Although grape production is fixed for most varieties within a given season, some supply flexibility is possible with raisin grapes because these varieties may also be dried. Thus, demand for raisin grapes for crushing is assumed to be jointly determined with the supply and derived demand of grapes for drying. All grape demand equations and raisin grape supply function (a system of five equations) are considered interdependent in estimation because the error terms of the crush demand equations are assumed to be contemporaneously correlated. They were, therefore, estimated by three-stage least squares (3SLS).[4] On the other hand, the wine production and price equations are assumed to be recursive and were estimated by ordinary least squares (OLS).

Discussion of the Results

Estimates of the grape-crushing demand equations are presented in table 1. Expected parameter signs based on the theoretical specification are indicated below the estimated standard errors. Overall, the results are satisfactory. The weighted R^2 of the system is 0.91, suggesting that the predetermined variables of the system explain much of the variation in the dependent variables. Also, the Durbin-Watson statistics of the equations estimated by OLS did not indicate any evidence of serial correlation.

With the exception of the insignificant coefficient of lagged wine price in the wine grape demand equation, all estimates have the predicted signs. Negative own-price flexibilities are indicated for each of the three grape types (−1.46, − 0.14, and −1.62 for wine, table, and raisin grapes, respectively, at the sample means). In all three equations, expected normal wine demand (as reflected in one-year lagged shipments) and beginning stocks have a strong effect on grape prices. This supports the view that factors which influence inventory investment also influence raw material purchases. The weak performance of lagged wine price may reflect that either measurement difficulties are present or that demand changes are captured mainly by lagged wine shipments.

Estimates of the production equations for table and dessert wines are reported in table 2.[5] With the exception of the insignificant coefficient on lagged table wine price in the first equation, all estimates have the anticipated signs. Changes in production rates are primarily accounted for by changes in grape prices, lagged wine shipments, and beginning inventories. The large estimated coefficient on lagged wine shipments in the table wine equation indicates that aging is relatively important for this commodity.

In the table wine price equation, table 3, all variables are significant and have correctly an-

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[4] The results for derived demand and supply of raisin grapes for drying are not reported, but can be obtained from the author.

[5] Because of high intercorrelation among the grape prices in the production and price equations, they were replaced by a price index with weights based on the relative importance of each input in total crushings (i.e., $W_i = X_i/\sum_i R_i X_i$). The weights are 0.85, 0.39, and 0.96 for wine, table, and raisin grapes, respectively.

Table 1. Estimated California Winery Demand for Grapes, 1951–74

Price of Grape i	Explanatory Variables									
	Constant	X_{wgt}	X_{tgt}	X_{rgt}	C_t	P_{t-1}	S_{t-1}	ΔS_{t-1}	K_t	T
Wine	124.512	−0.1761	0.0313	−0.0115	−0.8733	−0.6056	2.0167	−1.3118	−0.5696	−0.4543
grapes,	(86.9995)[a]	(0.0568)	(0.0414)	(0.0549)	(1.3496)	(0.7615)	(0.2631)	(1.1553)	(0.3036)	(2.5506)
R_{wgt}		(−)[b]	(?)	(?)	(−)	(+)	(+)	(?)	(−)	(?)
Table	116.539	0.0307	−0.0183	−0.0878	−1.1752	0.3933	0.8571	0.6966	−0.7230	2.3991
grapes,	(55.6999)	(0.0364)	(0.0266)	(0.0349)	(0.8658)	(0.4906)	(0.1657)	(0.7432)	(0.1916)	(1.6385)
R_{tgt}		(?)	(−)	(?)	(−)	(+)	(+)	(?)	(−)	(?)
Raisin	88.1041	0.0779	−0.0170	−0.1023	−1.0691	0.6990	0.6561	1.1575	−0.7432	2.6601
grapes,	(82.1318)	(0.0537)	(0.0392)	(0.0514)	(1.2798)	(0.7224)	(0.2445)	(1.0949)	(0.2828)	(2.4139)
R_{rgt}		(?)	(?)	(−)	(−)	(+)	(+)	(?)	(−)	(?)

Sources and Notes: R_t is farm price of grapes crushed, \$/ton (Calif. Crop and Livestock Reporting Ser.): X_t is quantity of grapes crushed, 1,000 tons (Calif. Crop and Livestock Reporting Ser.); C is index of processing and marketing prices, 1967 = 100 (see text); P is index of FOB wine prices, 1967 = 100 (Wine Institute, *Wine Institute Bulletin*); S is quantity of all California-produced wine and brandy sold in the United States, mil. gal. (Wine Institute, *Wine Institute Bulletin*); K is 1 July inventory of all California-produced wine and brandy, mil. gal. (Wine Institute, *Wine Institute Bulletin*). All price variables were deflated by the consumer price index. Equations estimated by 3SLS.

[a] Values in parentheses are estimated standard errors.

[b] Expected coefficient signs as shown in text, and (?) refers to an indeterminate sign.

Table 2. Estimated California Prodnction of Table and Dessert Wines, 1951–74

Production of wine j	Explanatory Variables									
	Constant	R_t	C_t	P_{jt-1}	S_{jt-1}	ΔS_{jt-1}	K_{jt}	T	R^2	d[a]
Table	128.841	−0.3650	−0.3474	−0.6109	2.8251	−0.4694	−1.2250	0.1687	0.992	1.90
wine,	(55.6950)[b]	(0.0806)	(0.4714)	(0.3339)	(0.2431)	(0.4799)	(0.1812)	(0.7773)		
Q_{twt}		(−)[c]	(−)	(+)	(+)	(?)	(−)	(?)		
Dessert	142.146	−0.2094	−1.4167	0.2998	0.9538		−0.9053	0.8129	0.816	1.45
wine,	(58.5122)	(0.0742)	(0.7312)	(0.2938)	(0.3925)		(0.2127)	(1.0846)		
Q_{dwt}		(−)	(−)	(+)	(+)		(−)	(?)		

Sources and Notes: R is index of farm prices of grapes crushed, 1967 = 100 (Calif. Crop and Reporting Service); C (see table 1); P_j is FOB wine price, 1967 = 100 (Wine Institute, *Wine Institute Bulletin*); S_j is quantity of California-produced wine sold in the United States, mil. gal. (Wine Institute, *Wine Institute Bulletin*); K_j is 1 July stock of California-produced wine, mil. gal. (Wine Institute, *Wine Institute Bulletin*). All price variables deflated by the consumer price index. Equations estimated by OLS.

[a] Durbin-Watson statistic. All values fall in inconclusive range at 5% significance level. See Savin and White, p. 1994.

[b] Values in parentheses are estimated standard errors.

[c] Expected coefficient signs.

Table 3. Estimated California Prices of Table and Dessert Wines, 1951–74

Price of Wine J	Explanatory Variables										
	Constant	R_t	C_t	P_{J-1}	S_{J-1}	ΔS_{J-1}	K_J	T	R^2	d[a]	h[b]
Table wine, P_{twt}	13.6189 (18.7492)[c]	0.0594 (0.0271) (+)[d]	0.5008 (0.1587) (+)	0.3214 (0.1124) (+)	0.1999 (0.0818) (+)	−0.6703 (0.1616) (?)	−0.1816 (0.0610) (−)	0.1425 (0.2617) (?)	0.891	1.57	1.26
Dessert wine, P_{dwt}	−46.9193 (45.1451)	0.0424 (0.0481) (+)	1.5095 (0.4740) (+)	0.3988 (0.1905) (+)	−0.2202 (0.2545) (+)		0.0949 (0.1379) (−)	−2.2926 (0.7031) (?)	0.906	2.04	0.27

Sources and notes: See table 2.

[a] Durbin-Watson statistic.

[b] Durbin-H-statistic. No significant autocorrelation at 5% level.

[c] Values in parentheses are estimated standard errors.

[d] Expected coefficient signs.

ticipated signs. Note that lagged wine shipments and beginning inventories have a strong influence on table wine price. The influence of these variables is often ignored in estimating price equations. Similar results have been obtained by Maccini (1978) for U.S. manufacturing in total and for sectoral data for several manufacturing groups. He also finds that expected normal demand is an important determinant of price behavior. Note also that lagged table wine price plays a minor role. Most of the variation in price is explained by other variables in the equation.

The results for dessert wine price are not as successful as those for table wine. Lagged wine shipments and beginning inventories are insignificant, with most of the variation absorbed by the time trend and the lagged price.

Conclusions

This paper has developed a dynamic model of processor behavior and presented econometric results for the California wine industry. The theoretical specification and empirical results emphasize interconnections between the shadow price of inventory and processor behavior on raw material demand, production, and output price determination. Expected normal wine shipments and beginning inventories were found to have strong effects on grape demand and wine prices as well as wine production. Past studies frequently have ignored these factors or modeled them in an arbitrary way. The results also indicate that a distinction should be made between transitory and permanent demand and cost changes. The shadow price of inventory depends upon expectations of all future demand and cost functions. With "quasi-rational expectations," demand and cost changes in previous periods matter. This suggests caution in using models derived from static theories to characterize processor behavior.

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Private Investment in Forest Management and the Long-Term Supply of Timber

Darius M. Adams, Richard W. Haynes, George F. Dutrow, Richard L. Barber, and Joseph M. Vasievich

Timber supply behavior of private forest owners is a major uncertainty in long-term forest product market projections. A model of private supply is developed that explains both harvest and forest management investment decisions. Comparison of two fifty-year projections, one assuming constant management intensity and a second using the harvest-investment model, indicates that projected levels of investment would (*a*) have little impact on markets prior to the year 2000, (*b*) stabilize real wood product prices after 2000, (*c*) eliminate softwood lumber imports by 2030, and (*d*) expand the dominant role of southern forest regions in wood product markets.

Key words: forest management, timber supply, wood prices.

Since the first national assessment of U.S. timber supply prospects more than a century ago (Hough), one of the principal uncertainties in projecting future harvest levels and inventories has been the supply behavior of private forest owners. Two aspects of private supply behavior are important: (*a*) the volume of timber private owners will harvest from existing inventories under various price and market conditions, and (*b*) the investments private landowners will make in forest management (planting, thinning, and fertilization) that will influence the growth of inventory and future harvest levels. Some empirical work exists on the "short-term" harvest question, and there is a substantial body of theory about the "long-term" investment question. There has been little effort, however, to combine available empirical and theoretical structures in a comprehensive model of timber supply and forest management investment over time.

This paper presents an integrated model of private timber supply that incorporates both harvest and investment behavior. The implications of this supply model are explored by combining it with a model of final product markets. The combined model was used for two fifty-year projections of U.S. timber prices, harvest, and consumption. In the first simulation, only the short-term harvest mechanism is used. Investment and intensity of private management are assumed to remain constant at recent levels. The second simulation considered both short- and long-term aspects.

Results suggest that investment behavior of private owners will have a major impact on anticipated long-term price and consumption behavior in forest products markets. With the investment levels projected by the model, simulated prices of forest products are stabilized by the first decade of the next century, while stumpage prices rise at first but then return to near current levels at the end of the simulation period. Ignoring investment, simulated prices continue to rise at rates at least as high as those observed in the past two decades. Results also confirm that intensified management will have little impact on product or stumpage markets in any region prior to the year 2000. Thus, public policies designed to augment timber supply in regions currently experiencing declining harvest must rely on expanded harvest from public lands rather than accelerated investment on private lands if they are to be effective in the short term. Finally, investment behavior as depicted by the model will lead to further concentration of both timber and product output in the South.

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Simulated production in the West increases, but the South's investment potential is so much greater that it will expand its dominant role in U.S. markets by the year 2030.

Previous Studies

Two distinct approaches have been employed in previous studies of private timber supply. The first uses mathematical programming to schedule short-term private harvests consistent with maximization of some objective (Berck, Rahm). Investment in intensive management occurs at a prespecified rate external to the model. Typically, the rate has not depended on prices, costs, or other financial considerations. The second approach is to estimate the relationship between current period harvest, stumpage price, and some proxy for the costs of holding timber inventory (McKillop, Robinson, and Adams). This approach concentrates on short-term supply response, ignoring intertemporal linkages of harvest decisions and long-term investment decisions.

An Integrated Supply Model

The integrated private supply model proposed here consists of three elements:

(*a*) A set of short-term, regional stumpage supply or harvest relations which interact with stumpage demand relations to determine current harvest and stumpage price. There is one supply relation for each of two classes of private owners, industrial and nonindustrial, in each of eight U.S. supply regions. The stumpage supply relations depend on price and on timber inventories held by each owner group.

(*b*) An inventory projection model that updates the inventory volumes used in the stumpage supply equations. At the start of each simulation period, inventory volume equals the lagged inventory plus growth, less natural mortality and harvest during the previous period.

(*c*) A model that determines investment in forest management practices and adjusts the parameters of the inventory projection model. In general, higher rates of investment mean higher rates of forest growth and lower rates of natural mortality. The decision to invest depends on the prospective present net worth of each investment alternative and, hence, on anticipated physical yields, investment costs, and stumpage prices.

The private harvest-investment model is embedded in a larger model of U.S. forest products and stumpage markets developed by Adams and Haynes. The market model is spatially disaggregated, with six domestic consuming regions and eight domestic supplying regions plus Canada. Each region has either demand or supply equations (as appropriate) for each final product. The regional supply equations for each final product, e.g., lumber or plywood, depend on the stumpage sector by means of a stumpage price (factor cost) term. Aggregate stumpage demand is derived from the supply processes for all products. The short-term stumpage supply relations from the harvest-investment model reflect the harvest response of private owners, while harvests from public lands (which are not price sensitive) enter as exogenous additions to total supply. Spatial equilibrium is computed in the final product sector by means of a reactive programming algorithm (King and Ho). Associated equilibria in the eight regional stumpage markets are found by equating aggregate stumpage demand and total stumpage supply. Investment affects market activity and prices by augmenting growth, increasing inventories, and thereby shifting the short-term private stumpage supply equations to the right. Market activity and prices influence investment via the price expectation mechanism in the investment model. The following sections describe the harvest-investment model in further detail.

Short-Term Private Stumpage Supply

Private stumpage supply equations were patterned after those developed by Adams and take one of two forms depending on region and owner group:

$$(1) \qquad h_{r,t}{}^{o} = \alpha + \beta\, p_{r,t} + \gamma\, I_{r,t-1}{}^{o}, \text{ or}$$

$$(2) \qquad h_{r,t}{}^{o}/I_{r,t-1}{}^{o} = \delta + \epsilon\, p_{r,t},$$

where $h_{r,t}{}^{o}$ is timber harvest in period t, region r, owner o; $p_{r,t}$, stumpage price in period t, region r; $I_{r,t-1}{}^{o}$, timber inventory volume at the end of period $t - 1$ (start of period t), region r, owner o; and α, β, γ, δ, ϵ are parameters. Selection of either form (1) or (2) was based on goodness-of-fit and residuals characteristics for each region/owner group. In general, form (2) was adopted for industrial owners in the West, while form (1) was employed for nonindustrial owners in the West and all owners in the East. One basic distinction between these groups is that western industrial owners generally hold large inventories of old-growth timber which fell in volume over the sample period (1950–76), while western nonindustrial and eastern owners held generally smaller inventories of young-growth timber that have been increasing in volume.

Price and inventory elasticity estimates derived from equations (1) and (2) show consistent differences among regions and between owner groups. Comparing western and southern regions, price elasticities are generally higher in the South (.41 versus .17) while inventory elasticities are higher in the West (1.10 versus .57). Across all regions, price elasticities for industrial ownerships average 67% greater than those for nonindustrial owners.[1] The West-South differences in price elasticities reflect markedly different land ownership patterns in the two regions and the more active private stumpage markets in the South. In the West, timber ownership is heavily concentrated in industrial ownerships. The bulk of this timber flows from woods to mill without entering a stumpage market. Nonindustrial lands are a minor wood source and procurement efforts by processors are limited. In contrast, industrial lands are of minor importance in the South. The bulk of the timber consumed in this region is purchased through various marketing arrangements from nonindustrial owners. Causes of the differences in inventory elasticities are less clear. One conjecture is that inventory-holding costs (taxes, protection, and annual operation) are higher in the West than in the South because western rotations are longer. Hence, a given inventory change leads to a greater cost change and supply response in the West.

Higher price elasticities for industrial owners, regardless of region, are consistent with variations in ownership objectives. Ownership studies and surveys of owner intentions suggest that nonindustrial owners often do not retain woodlands for reasons of profitability or as a source of income. In many western regions, nonindustrial harvest has actually fallen in some periods, while price and inventory have been increasing. In contrast, profitability and sensitivity to short-term movements are important to industrial owners. Thus, it is reasonable to observe greater price responsiveness in industrial supply.

Inventory Projection Model

The model of forest growth used to project timber inventories over time was derived from the TRAS system developed by Larson and Goforth. The inventory of each region/owner group is characterized by its distribution of number of trees per acre by diameter class. Over time, growth is simulated by the advancement of trees from smaller to larger diameter classes depending on diameter growth, loss due to natural causes, and removals from each class with harvesting. Growth of trees into the smallest diameter class is estimated by an "ingrowth" rate.

Investment in intensive management involves using some mix of intensive forestry treatments. A recent study by the Forest Industries Council provides the basic data on treatment alternatives, their financial and yield characteristics, and the acreage suitable for treatment in the timber-producing regions of the United States. Treatments were identified as those growth-augmentating practices currently available for existing conditions on commercial timberlands. They include planting, thinning, fertilization, and species conversion (from hardwoods to softwoods).

The investment model determines the treatment mix to be adopted in a given region/owner group and the number of acres to be treated over time. Using the Forest Industries Council data, it was then possible to compute the prospective increase in growth per acre on the treated acres beyond that from current management. By combining treated and untreated acres, an estimate of total increase in growth was then obtained. It was assumed that the growth per acre simulated by the inventory projection model with initial parameters (initial diameter growth, mortality, and ingrowth rates) was an accurate estimate of the growth under continued current management. The effects of management intensification were then simulated by changing model parameters to yield a per acre growth rate equal to the sum of current growth plus an increment resulting from adoption of the specific treatment mix.

The adoption of a particular treatment mix does not immediately increase forest growth by the full potential increment. Land is gradually shifted into intensive management. Also, the growth impacts of any given treatment are realized gradually after its initiation. Thus, changing growth parameters in the inventory projection model does not involve a one-time shift at the time of investment. Details of this calibration process are given in a paper by Barber.

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[1] All elasticity differences are significant at the .05 level.

Long-Term Investment Model

Private owners are assumed to be economically rational in their investment activities. Forest management practices are adopted only if they promise to yield a positive present net worth, given expected stumpage prices, investment costs, yields, and owners' discount rates.[2] A real discount rate of 4% was assumed for all owners. Other owner objectives are ignored. However, constraints on the rate of investment imposed by limited availability of capital are recognized. Private owners also are assumed to recognize the effects of current investment on future stumpage supplies and prices. That is, their price expectations are rational.

The model works as follows. In each year of the projection period, private owners survey a list of potential investments, analyzing their present net worths. For each treatment with positive present net worth and for which some untreated acreage remains, a fraction of the untreated acreage (termed the "enrollment rate") receives that treatment. In this process, the treatment mix adopted over time can vary. For example, treatment i in a particular region/owner group may have a positive present net worth in year t, leading to some investment. In year $t + k$, however, expected future prices may have changed or all treatable acres may have been previously enrolled so that treatment i may not appear in year $t + k$'s investment mix.

Price expectations. As investment proceeds over time, forest growth gradually will increase and with it the inventory level. This will in turn shift the short-term private supply relations, changing future harvests and stumpage prices. Owners are assumed to recognize this interrelation between current investment and future prices. The mechanism adopted for adjusting price expectations was to replicate the entire projection process several times, using as expected prices in iteration k the prices projected in iteration $k - 1$. The process was stopped when the differences between prices in succeeding iterations were less than a small, fixed tolerance. For treatments with investment lifetimes longer than fifty years or adopted so late that some or all of their returns occur after the end of the projection, expected prices were held at the level of the projection period's last year.

Enrollment rate. Assuming economic gain to be the sole objective and ignoring any investment constraints, all treatments with positive present net worth would be undertaken immediately by private owners. However, the investment capital required for immediate implementation of all treatments in the Forest Industries Council study would be about $12 billion at current prices, far exceeding the capabilities of industrial and particularly nonindustrial owners. Investments likely would be made gradually over time as funds became available, with only some fraction of the treatable acreage enrolled each year. Because there is little data on actual investment, it was assumed that if a treatment had a positive present net worth in a given year, the enrollment rate in that year would be A_i/d_i acres, where A_i is the treatable acreage identified in the Forest Industries Council study, and d_i is the investment lifetime of alternative treatment i expressed in years.

Investment rates are commonly assumed to be directly proportional to profitability in natural resource development models. The A_i/d_i rule is partially consistent with such profitability rules. Within a given region/owner group, the rule yields higher enrollment rates for investments with shorter durations (this approximates a "payback period" criterion). Within any given category of treatments, duration is inversely related to site quality, while profitability is positively related. Thus, for a given treatment which may be practiced on a range of site qualities, the A_i/d_i rule leads to more rapid enrollment of high quality lands and hence of alternatives with higher present net worths.

Across regions, the A_i/d_i rule yields higher enrollment rates in regions with shorter average investment duration and larger treatable acreage. This involves potentially higher enrollment rates in the South than in the West, because durations are longer and treatable acreage is smaller in the West. Historically, this is generally what has occurred. Over the past two decades, annual area planted or seeded in the South has averaged more than three times that on the Pacific Coast. In some specific years, it has been more than six times larger. Per acre of commercial forest land, southern regeneration is 21% higher than in the West. Annual area given intermediate stand treatments (thinning) has averaged about 2.5 times larger in the South than in the West and in some years has been nearly six times larger (USDA Forest Service 1980, pp. 462–6).

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[2] All prices and costs are in real terms deflated by the all commodity producer price index (1967 = 1.0).

Simulation Results

Using the models described in the preceding sections, two contrasting projections were developed for the U.S. forest products economy over the next five decades. In the first "baseline" simulation, the product and stumpage markets were projected assuming that the intensity of management on private lands is held at current levels. Given historical trends toward increased intensity, the baseline simulation is a conservative view of potential timber supply. The second simulation, termed the intensive management projection, employs the private harvest-investment process and allows private management intensity to vary as determined by the model.

In the intensive management simulation, land enrollment in intensive treatment programs was substantial. Table 1 indicates the acreage enrollment and number of treatments utilized for four critical southern and western regions. In the South, all available treatments are employed, and nearly 87% of the treatable acreage was enrolled (acreage treated/acreage treatable). Investments remain profitable in the South despite declining stumpage prices because of the high physical growth rates of southern forests. In the West, on the other hand, many treatments are noneconomic even with real price growth. This is particularly true in the California region, where only thirty of forty-five available treatments are employed. However, the extent of enrollment in the West (Douglas-fir and California regions) at 81% of treatable acreage is almost as large as in the South.

The initial impact of management intensification is to increase the growth of the private forest inventory relative to the baseline. As growth expands, the inventory also increases. Figure 1 displays growth and inventory characteristics for three critical region/owner groups, Douglas-fir industry, California industry, and southcentral other private. By 2030, growth under intensive management is about twice baseline levels in the West and nearly three times baseline levels in the South. By 2010, increased management intensity has stemmed the long-term decline in industrial inventories in the Douglas-fir region and led to increases in inventories in the California industry and southcentral other private groups.

Larger private inventories shift the short-term private supply relations, depressing stumpage prices and expanding cut relative to baseline levels. Figure 2 shows stumpage price paths for the Douglas-fir, California, and southcentral regions. By 2030, prices in the Douglas-fir region have returned to approximately their 1980 levels, while California prices are about $20 higher. The greatest price reductions occur in the southern regions because of the large increases in growth and inventory. Table 2 gives harvest volumes by region and major owner group. Management intensification in the South leads to substantially larger and earlier relative growth, inventory, and harvest increments than in the West.

Table 1. Summary of Treatment Characteristics under Intensive Management for Selected Region-Owner Groups

Region/Owner	Number of Treatments	2030 Growth Increase from Intensive Management	2030 Growth under Constant Management Intensity	Acreage Treated	Acreage Treatable	Total Ownership Acreage
	(utilized/ available)	(CF/acre/ year)	(CF/acre/ year)	------- (thousand acres) -------		
Southeast industrial	11/11	33.1	38.9	5,841	7,707	15,870
Nonindustrial	12/12	49.6	32.8	30,107	43,029	57,010
Southcentral industrial	13/13	50.5	24.7	15,938	16,025	23,820
Nonindustrial	13/13	61.5	20.9	45,752	46,029	58,330
Douglas-fir industrial	10/12	50.8	67.8	2,049	2,644	7,380
Nonindustrial	10/12	53.2	67.5	878	1,288	3,250
California industrial	30/43	81.7	60.2	1,551	1,871	2,890
Nonindustrial	30/43	69.8	64.5	3,063	3,488	4,220

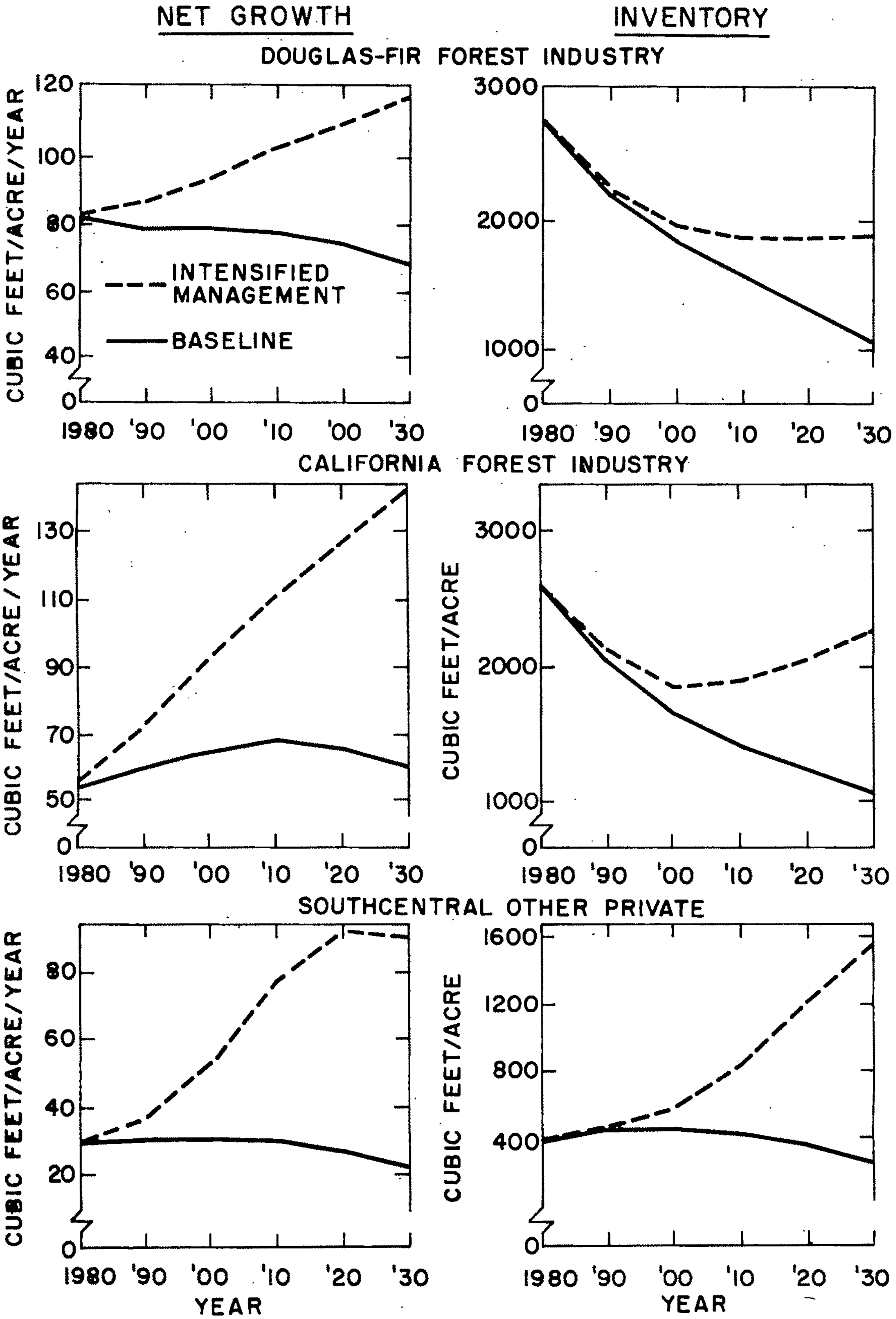

Figure 1. Net growth and inventory from baseline and intensive management simulations for

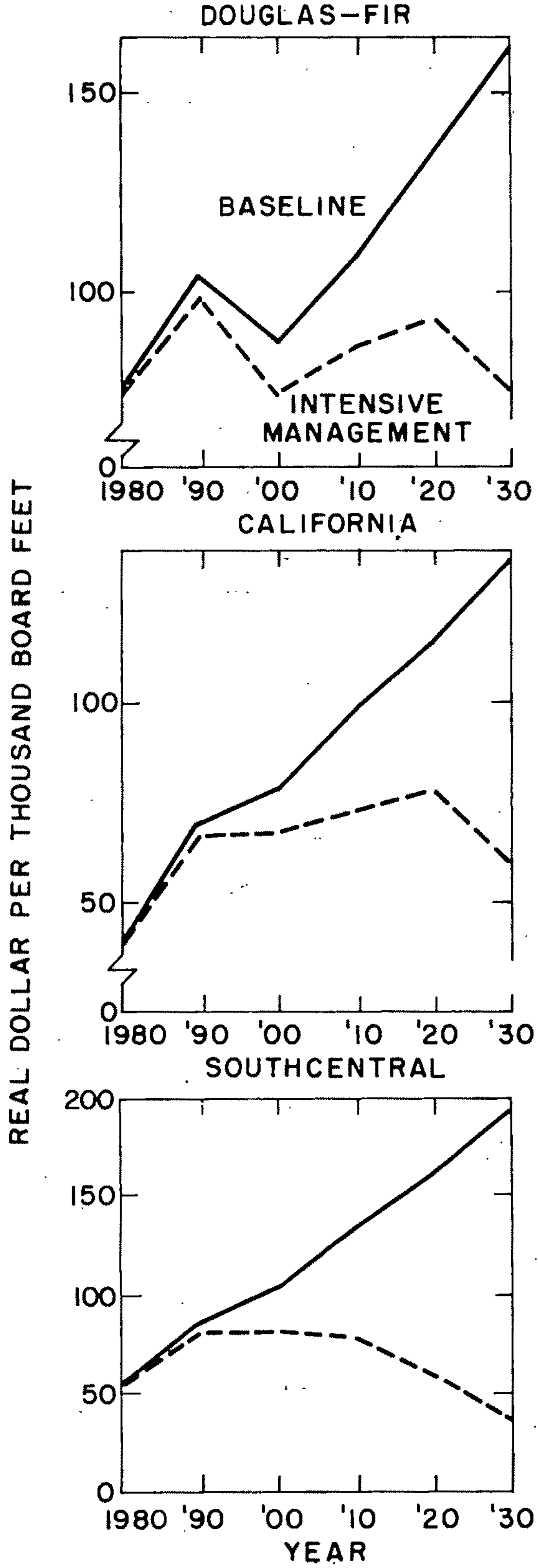

Figure 2. Stumpage prices from baseline and intensive management simulations for selected regions

Lower stumpage prices yield lower production costs for all final products (nonwood costs were assumed to remain at their baseline levels) and alter regional patterns of comparative advantage in final product markets. The greatest shift in costs occurs in the southern regions which, as a result, realize the greatest gains in product output and in harvest. These effects are clearest for the softwood lumber market. As indicated in table 3, levels and trends in regional shares of U.S. new supply (domestic production plus imports) are not markedly altered from the baseline simulation prior to 2000. After 2000, modest gains in market share are realized in the Douglas-fir region, but the greatest expansion occurs in the South. Total U.S. new supply increases by about 6 billion board feet by 2030, accounting for some of the market share gains. Major gains also occur because of domestic substitution for lumber imports from Canada. By 2030, the intensive management simulation indicates that Canadian lumber would no longer be competitive in U.S. markets.

Nationally, intensified management leads to expanded domestic production of wood products, lower prices, increased consumption, and reduced dependence on imports. Table 4 summarizes these impacts for softwood lumber and plywood. Prices of softwood lumber and plywood grow rapidly in both simulations from 1980 to 2000. Rates of price growth fall sharply after 2000, averaging 0.1% or less in the intensive management simulation. Domestic lumber production is 16.3 billion board feet higher by 2030, while domestic consumption is up only 6.3 billion board feet. The 10.0 billion board foot difference is replacement of Canadian lumber imports. Softwood plywood production and consumption rise by identical, modest amounts.

Conclusion

The U.S. Forest Service has consistently identified rising real forest products prices as a key forest policy issue (USDA Forest Service 1965, 1973, 1980). Over the past several decades, real prices of lumber have risen steadily at an average rate of about 1.5% per year. Plywood prices have risen at least as fast since the early 1960s. Rising prices have led to expanded use of nonwood products, causing market losses for forest products producers. The Forest Service also has argued that substitution may entail additional environmental

Table 2. Total and Private Timber Harvest from Baseline and Intensive Management Simulations

Region/Simulation		1990 Total	1990 Private	2000 Total	2000 Private	2030 Total	2030 Private
		(million cubic feet)					
Douglas-fir	Baseline	2,468	1,442	2,230	1,154	2,140	997
	Intensive	2,462	1,436	2,247	1,171	2,283	1,139
California	Baseline	905	553	875	518	932	554
	Intensive	903	551	890	533	1,023	645
Rockies[a]	Baseline	1,626	652	1,711	646	2,166	719
	Intensive	1,623	649	1,694	633	1,315	1,044
North	Baseline	890	715	1,011	799	1,322	1,051
	Intensive	890	715	1,010	798	1,315	1,044
South	Baseline	5,687	5,344	6,238	5,854	7,515	7,007
	Intensive	5,730	5,387	6,462	6,078	9,649	9,168
Total U.S.	Baseline	11,576	8,706	12,065	8,971	14,075	10,328
	Intensive	11,608	8,738	12,303	9,213	16,115	12,608

[a] Includes eastern Oregon and Washington and Rocky Mountain states.

and social burdens because many nonwood products are derived from nonrenewable resources, are more energy-intensive in production, and generate greater pollution in both manufacture and consumption (USDA Forest Service 1980).

Results of the intensive management simulation suggest that there is sufficient potential for expanding timber growth across the several forest regions of the United States to stabilize wood product prices by the year 2000. Under the assumptions of the harvest-investment model, these results are obtained through the actions of private, profit-seeking investors. Alternatively, the results may be viewed as indicating the extent of management intensification that would have to be stimulated by some combination of private profit-seeking and public incentive, assistance, and/or regulatory programs if achievement of stable wood products prices in the next century were an objective of public policy.

The future of various forest regions would be significantly altered by the widespread adoption of intensive management practices. In the baseline simulation, the eastern and Rocky Mountain regions appear to have major opportunities for harvest and product output expansion, while the Douglas-fir and California regions do not. Both of the latter are nearing the end of liquidation of old-growth timber stocks on private lands. They face problems of transition to young-growth. Declining harvest will cause employment and income losses. These will be major shocks to some local economies. Understandably, there is intense interest in public policy measures to modify or eliminate these economic problems.

A commonly suggested policy is to subsidize, encourage, or regulate intensified management. Results of this simulation do indicate that the declining trends in inventory (fig. 1) and harvest (table 2) may be stabilized or even reversed by increased investment in the Douglas-fir and California regions. In neither area, however, can any major impact be expected prior to the year 2000. Although some short-duration treatment opportunities (such as commercial thinning) do exist, the bulk of available investments produce results only after forty or more years. Thus, investment appears to solve long-term problems, but some means must be found to bridge the gap between current (declining) and future (stable to rising) harvests after 2000. The most likely sources of additional short-term supply in the

Table 3. Shares of Total U.S. New Supply of Softwood Lumber by Region from Baseline and Intensive Management Simulations

Region/Simulation		Percentage of Total U.S. New-Supply of Softwood Lumber 1990	2000	2030
Douglas-fir	Baseline	12.6	9.5	15.2
	Intensive	12.5	9.9	15.6
California	Baseline	12.6	12.7	14.3
	Intensive	12.6	12.7	13.7
Rockies	Baseline	18.9	20.4	27.4
	Intensive	18.9	19.7	19.1
North	Baseline	2.9	2.2	3.9
	Intensive	2.9	2.2	3.4
South	Baseline	24.2	22.4	16.3
	Intensive	24.9	26.1	48.2
Canada	Baseline	28.7	31.8	23.0
	Intensive	28.2	28.5	0

Table 4. Prices, Consumption, and Production of Softwood Lumber and Plywood from the Baseline and Intensive Management Simulations

		1990	2000	2030
Producer price index softwood lumber (1967 = 100.0)	Baseline	200.0	225.2	296.2
	Intensive	195.8	217.5	225.6
Producer price index softwood plywood (1967 = 100.0)	Baseline	193.7	200.7	231.3
	Intensive	192.7	196.2	198.4
U.S. consumption softwood lumber (billion bd. ft.)	Baseline	42.6	41.7	42.4
	Intensive	42.6	42.5	48.7
U.S. consumption softwood plywood (billion sq. ft.)	Baseline	21.8	22.0	22.1
	Intensive	21.9	22.3	24.8
U.S. production softwood lumber (billion bd. ft.)	Baseline	31.4	29.4	33.6
	Intensive	31.7	31.4	49.9
U.S. production softwood plywood (billion sq. ft.)	Baseline	22.7	22.8	22.7
	Intensive	22.8	23.1	25.4
U.S. lumber imports from Canada (billion bd. ft.)	Baseline	12.7	13.7	10.9
	Intensive	12.4	12.5	0.0

two regions are national forest lands, through so-called "departures" from current nondeclining, even-flow harvest policies. Departures allow a temporary increase in national forest harvest without jeopardizing the forest's ability to sustain their base even-flow harvest level. While departures may be technically feasible, they have been the focus of considerable controversy among industrial and environmental groups.

Another consequence of management intensification is to shift more productive capacity to the South. In 1950, the South produced no softwood plywood and about 46% of total U.S. woodpulp. By 1980 the South produced roughly 38% of U.S. softwood plywood and 60% of U.S. woodpulp. Southern expansion has been possible primarily because of lower labor and stumpage costs and, because of its proximity to major markets, lower transportation costs. The baseline simulation projects a continuation of past trends with the South's share of total softwood harvest rising from roughly 45% in 1980 to 53% by 2030. However, the investment trends depicted in the simulation accelerate production concentration in the South, leading to a 60% share of softwood harvest by 2030.

This result is a direct consequence of the many potentially treatable acres in the South and of the specific enrollment rule employed in the simulation. From the Forest Industries Council study, only the South and the Douglas-fir and California regions have significant opportunities for increasing growth through intensive management. The South has roughly nine times the commercial forest acreage of the Douglas-fir and California regions combined but nearly twelve times the treatable area. Thus, even by halving or quartering the South's enrollment rate and acreage treated, the region would continue to expand output relative to the West.

Recently, some forestry interest groups have advocated the adoption of a national policy seeking a net surplus in U.S. international forest products trade. Intensification of forest management at the levels discussed in this paper appears to offer the only means of achieving this ambitious goal. In the baseline simulation, the United States is a net importer throughout the projection period. By 2030 net imports are 2.3 billion cubic feet. Intensive management increases total U.S. supply in 2030 by 2.1 billion cubic feet, reducing lumber imports by 1.7 billion cubic feet. The remaining supply increment expands U.S. domestic lumber and plywood markets and reduces domestic prices. International trade other than lumber imports was held constant in both the baseline and intensive simulations. However, lower U.S. product prices would improve the competitive position of U.S. producers relative to world producers, leading to improvements in the net trade position beyond that shown in the simulations.

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ERRATA

Editor's Note: The editors apologize for and wish to correct two errors that were discovered in the February 1982 *Journal* article, "Farm Real Estate Price Components, 1920–78," by Emery N. Castle and Irving Hoch. Both errors occur on page 15, in table 2. The title of the table should appear as follows:

Table 2. Predicted and Actual Prices, Selected Years (in Constant Dollars, 1967 = 100)

The second error occurs in the third column heading: V_{2t} should read V^*_{2t}.

Notes

The Countercyclical Aspects of the U.S. Meat Import Act of 1979

James R. Simpson

The U.S. Meat Import Act of 1979, the so-called "countercyclical" meat import bill, was signed into law on the last day of that year by President Carter. This law, which reflects a desire to help stabilize the fluctuations that have taken place in cattle inventory numbers and prices, has received wide attention by the U.S. livestock industry and countries exporting to the United States (Reeves 1979, U.S. Congress). There is evidence that the United States is a price maker at the international level as a result of being the world's largest beef importer, producer, and consumer (Simpson). Consequently, a major change in the U.S. meat import law can be expected to have a tangible influence on international trade in beef and the policies set by both beef exporting and importing countries as well as on the U.S. cattle industry.

The purpose of this note is to analyze some potential effects of the new U.S. meat import law under two radically different assumptions about change in cattle inventory to determine if the act really is "countercyclical," i.e., resulting in a higher import quota when U.S. beef production is declining and vice versa, in a lower quota level when U.S. production is increasing.[1] It is not intended as a comparison with the 1964 law, which has been evaluated in the documents prepared by the U.S. Congress. It goes beyond the work of Weeks, whose concern was evaluating the two laws under two different production situations. It also builds on the work of Reeves (1980), Nelson et al., and Conable, who clarify and examine various aspects of the new law. Apart from analyzing the law's potential effect on the domestic beef cattle industry, these results contain implications for further refinements in such stabilizing schemes.

The Meat Import Act of 1979

The new law was designed to permit greater meat imports when domestic supplies are low and consumer prices high, thus supposedly moderating the rise in beef prices. On the other hand, it is supposed to reduce meat imports when domestic supplies are abundant and consumer prices low, thus moderating the decline in prices for producers. The law covers fresh, chilled, or frozen beef, veal, goat, and sheep meat. Lamb and pork are excluded as are cooked, preserved, and prepared meats and "high quality" beef processed into fancy cuts. However, noncooked portion control and prepared meats are included. A major change from the 1964 law is subtracting live cattle imports (other than breeding stock) from the domestic production of quota meats.

The new formula for determining the annual import quota as presented in the law is as follows:

$$\begin{matrix}\text{Annual}\\ \text{quota}\end{matrix} = \begin{matrix}\text{Average}\\ \text{annual}\\ \text{imports}\\ (1968\text{–}77)\end{matrix} \times \frac{\begin{matrix}\text{3-yr. moving average}\\ \text{of domestic production}\end{matrix}}{\begin{matrix}\text{10-yr. average of}\\ \text{domestic production}\\ (1968\text{–}77)\end{matrix}} \times \frac{\begin{matrix}\text{5-yr. moving average}\\ \text{of domestic cow beef}\\ \text{production}\end{matrix}}{\begin{matrix}\text{2-yr. moving average}\\ \text{of domestic cow beef}\\ \text{production.}\end{matrix}}.$$

The average annual imports of meat subject to quota for 1968–77 (the base) was officially set at 1,204.6 million pounds on a product weight basis. A floor of 1,250.0 million pounds is included.

The ten-year average of domestic production of quota meats for 1968–77 is 23,184.0 million pounds (carcass weight basis). From this the total carcass weight equivalents of live imports for 1968–77 (220 million lbs.) is subtracted. The moving average of domestic production of quota meats (1978–80) is 22,500.0 million pounds, from which the average total carcass weight of live cattle imports must be subtracted. The five-year moving average of domestic cow beef production, actually calculated on a per capita basis, is 17.4 pounds, while the two-year moving average (1979–80) is 13.4 pounds (the formula's cow beef component provides the countercyclical behavior of the formula). The re-

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Special thanks are due several anonymous reviewers who commented on this note.

[1] A detailed paper with a complete explanation of the method and assumptions, along with all data series, is available from the author.

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sult is that the formula for the 1980 quota, in millions of pounds is

$$AQ_{80} = 1{,}204.6 \times \frac{22{,}500 - 243}{23{,}184 - 220} \times \frac{17.4}{13.4},$$

which means

$$AQ_{80} = 1{,}204.6 \times 0.9692 \times 1.2985,$$

from which $AQ_{80} = 1{,}515.9966$ or 1,516 million pounds. Thus, the trigger level = 1,515.9966 × 1.1 = 1,667.5962 or 1,668 million pounds.

A "positive" quotient (greater than one) in the second term of the formula relating to cow beef supply means that imports can increase from the previous year's level. Section (h) stipulates that the president may suspend the quota by giving thirty days' notice (if certain conditions are met) when the quotient is positive, but the president may not increase the quota when the quotient is "negative" (less than one) except under quite stringent circumstances.

Projected Effect of the 1979 Law

The projections presented in the House Ways and Means Committee document (U.S. Congress) showing the relation between imports under the 1964 and 1979 import laws are interesting but of limited use in assessing the new law's value. It is not possible to reconstruct production levels from them. Furthermore, only one situation is presented. This precludes evaluation under various cattle inventory growth patterns. As a consequence, two radically different, yet possible, national herd growth scenarios are evaluated in this paper. The first one simulates a situation in which future cattle inventory behaves in a fashion similar to the last cycle—a peak of 132 million head in 1986 declining to 111 million head in 1990. The second scenario

Table 1. U.S. Beef and Veal Production, and Cattle Inventory, 1959–80, with Two Cattle Inventory Scenarios, 1981–90

Year	Commercial Beef and Veal Production[a]	Inventory, All Cattle		
			Projection	
		Historical[a]	Similar to Previous Cycle	Slow Increase
	– (Mill. lbs.) –	(1,000 head)		
1959	14,162	93,322		
60	15,399	96,236		
61	15,890	97,700		
62	15,867	100,369		
63	16,896	104,488		
64	18,965	107,903		
65	19,261	109,000		
66	20,355	108,862		
67	20,740	108,783		
68	21,358	109,371		
69	21,600	110,015		
70	22,030	112,369		
71	22,213	114,578		
72	22,647	117,862		
73	21,413	121,539		
74	23,286	127,788		
75	24,500	132,028		
76	26,480	127,980		
77	25,780	122,810		
78	24,610	116,375		
79	21,553	110,864		
80	21,245	110,961		
81			112,000	112,000
82			115,000	114,000
83			118,000	116,000
84			122,000	118,000
85			128,000	120,000
86			132,000	122,000
87			128,000	124,000
88			123,000	126,000
89			116,000	127,000
1990			111,000	128,000

[a] Source: *Livestock and Meat Statistics* and ESS/USDA estimates.

Table 2. Projections of U.S. Beef and Veal Production, 1980–90

	Total Commercial Production		3-Year Moving Average of Domestic Beef and Veal Production[a]	
Year	Similar to Previous Cycle	Slow Growth	Similar to Previous Cycle	Slow Growth
	(Mill. lbs.)			
1980	21,245	21,245	22,500	22,500
81	22,400	22,960	21,733	22,919
82	23,690	24,168	22,445	22,791
83	24,957	25,056	23,682	24,061
84	26,291	25,960	24,979	25,061
85	28,032	26,880	26,427	25,965
86	29,304	27,694	27,876	26,845
87	28,672	28,520	28,669	27,698
88	27,798	29,232	28,591	28,482
89	24,244	29,718	26,905	29,319
1990	22,977	30,080	25,006	29,677

[a] Only includes beef and veal because they make up 99.9% of quota meats.

simulates a slow increase in inventory all the way through the 1980s, with no cyclical turndown in the decade ahead. The actual situation likely will fall somewhere between these two extremes. The objective, however, is to test the extent to which the import quota would change under radically different situations, not to predict what actually will happen.

Production Projections

The first step in determining the U.S. annual meat import quota for 1981–90 is projecting total beef and veal production for those years. Because beef and veal make up about 99.85% of all meat falling under the meat quota, they are considered to be the only quota products for this analysis. The relation between the inventory of all cattle and total production for 1959–80 is provided in table 1. Production closely parallels inventory, with the production peak lagging inventory by about one year.

Total production (measured by commercial production) was divided by inventory to arrive at production per head of inventory, a value which is growing at an apparent annual rate of about 0.8%. This growth is a crude approximation of technological change (including management) and heavier carcass weights. Projections of beef productivity per head of inventory were made for the two alternatives on the basis of past experience. For example, projections from previous cycle behavior show production increasing until 1988 and declining rapidly as herd inventory reaches the bottom of the cycle. The slow-growth assumption portrays productivity continuously above the other alternative, and growing at an uninterrupted rate, at least to 1990.

The projections of beef and veal productivity per

Table 3. Projections of Cow Beef Production and Cow Beef Production per Capita, 1980–90

	Inventory Same As Previous Cycle				Slow Growth in Inventory			
Year	Total Production	Production per Capita	5-Year Moving Average	2-Year Moving Average	Total Production	Production per Capita	5-Year Moving Average	2-Year Moving Average
	(Mill. lbs.)	(lbs.)			(Mill. lbs.)	(lbs.)		
1980	3,328.8	15.0	18.6	15.1	3,328.8	15.0	18.6	15.1
81	3,360.0	15.0	17.2	15.0	3,416.0	15.2	18.6	15.1
82	3,450.0	15.2	16.3	15.1	3,534.0	15.6	16.4	15.4
83	3,540.0	15.5	15.2	15.3	3,712.0	16.2	15.4	15.9
84	3,660.0	15.9	15.3	15.7	3,894.0	16.9	15.8	16.6
85	3,840.0	16.5	15.6	16.3	4,140.0	17.8	16.3	17.4
86	5,280.0	22.5	17.1	19.5	4,392.0	18.7	17.0	18.3
87	5,120.0	21.6	18.4	22.1	4,650.0	19.6	17.8	19.2
88	4,920.0	20.5	19.4	21.1	4,914.0	20.5	18.7	20.2
89	4,640.0	19.2	20.1	19.9	5,207.0	21.5	19.6	21.0
1990	3,330.0	13.7	19.5	16.5	5,440.0	22.3	20.5	21.9

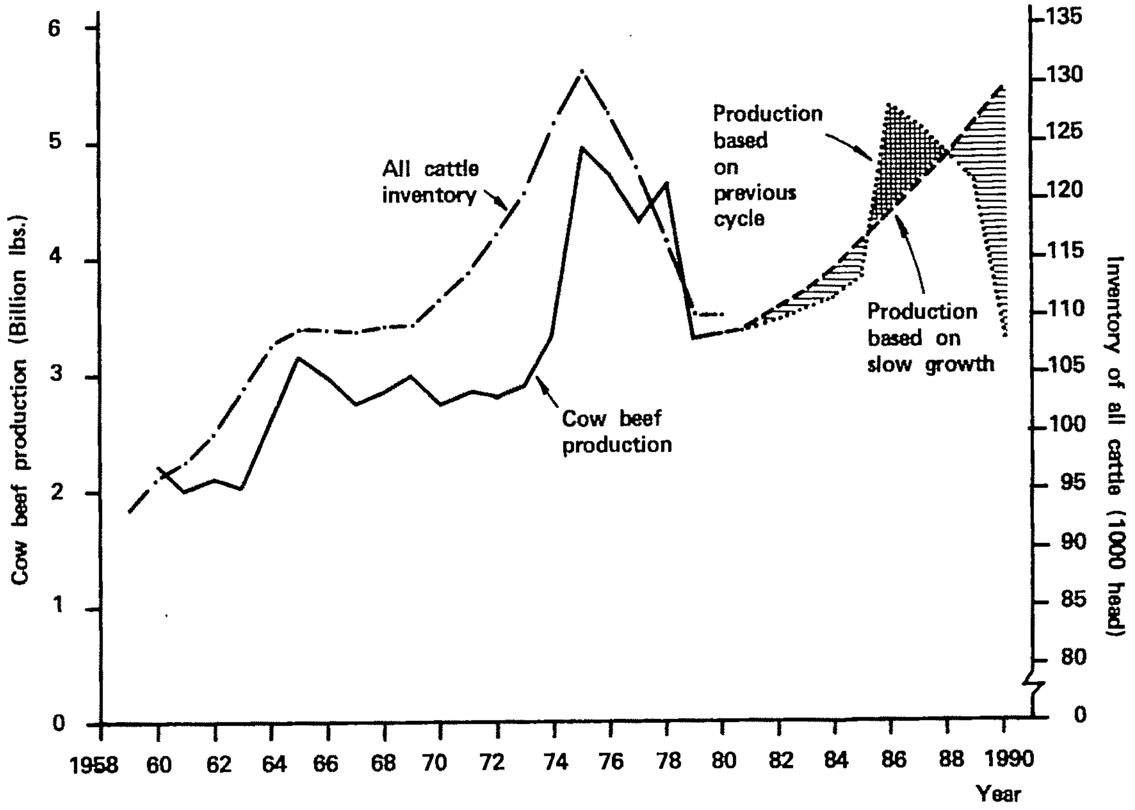

Figure 1. U.S. cow beef production compared with all cattle inventory, 1959–80, with cow beef production projections to 1990

head were multiplied by inventory projections to arrive at projections of total production (table 2). Under the past cycle assumption, production peaks at 29.3 billion pounds in 1986. Under the slow-growth assumption it continues to climb, reaching a maximum of 30 billion pounds in 1990. The three-year moving averages used in quota calculations are also given in table 2.

The second part of the annual quota formula requires projections of cow beef production. Total production of cow beef, just like all beef, was divided by total cattle inventory to arrive at cow beef

Table 4. Projections of U.S. Meat Import Trigger Level, 1980–90, under Two Assumptions

	Base Quota		Trigger Level		
Year	Inventory Growth Similar to Previous Cattle Cycle	Slow Growth in Cattle Inventory	Inventory Growth Similar to Previous Cattle Cycle	Slow Growth in Cattle Inventory	Congressional Projections of Trigger Level[a]
	(Mill. lbs.)				
1980	1,516.0	1.516.0	1,668.0	1,668.0	1,687.4
81	1,300.9	1,496.6	1,431.1	1,616.6	1,507.4
82	1,349.2	1,264.8	1,484.1	1,391.3	1,388.8
83	1,216.7	1,288.9	1,338.3	1,417.8	1,333.4
84	1,264.8	1,240.7	1,391.3	1,364.8	1,305.7
85	1,313.0	1,264.8	1,444.3	1,391.3	1,290.2
86	1,276.9	1,301.0	1,404.6	1,431.1	1,246.6
87	1,252.8	1,349.2	1,378.1	1,484.1	1,240.5
88	1,373.2	1,373.2	1,510.6	1,510.6	1,439.8
89	1,409.4	1,421.4	1,550.3	1,563.6	1,714.2
1990	1,529.8	1,457.6	1,682.8	1,603.3	—

[a] U.S. Congress.

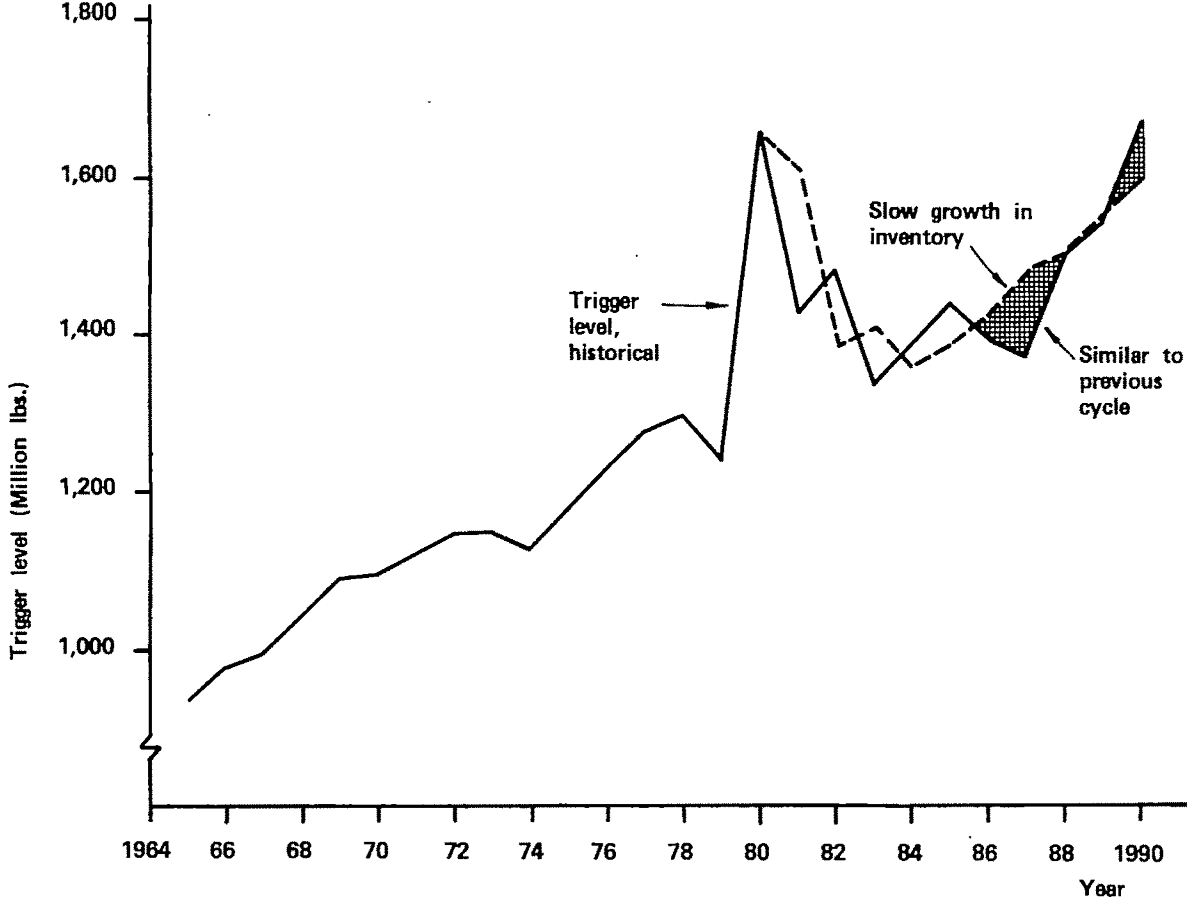

Figure 2. Trigger level on U.S. meat imports, 1965–80, with projections to 1990

production per head of inventory. The historical data show a clear upward trend caused largely by a decline in dairy cow numbers.

Production of cow beef per head of all cattle inventory probably will continue to increase during the 1980s but at a slower rate than during the past twenty-five years. Two cow beef production scenarios were developed. In the first, production of cow beef per head of inventory follows a pattern similar to that in the last cattle cycle, with the highest level (1986–89) at the same output (about 40 pounds of cow beef per head of cattle inventory) as in 1978. This projection corresponds to the all-cattle inventory projection based on the past cycle. The second projection involves a slow, steady inventory growth. As a result, production of cow beef per head of inventory increases continuously during the entire period. Multiplying cattle inventory by production per head yields the total cow beef productions given in table 3 and graphed in figure 1.

Calculations of Annual Quotas, 1981–90

The projections of total beef production shown in table 2 are translated into three-year moving averages in that table for both the previous cycle and slow-growth assumptions. This data is used in the numerator of the first term in the quota formula. In all cases, it was assumed that the imports of live cattle are equivalent to a carcass weight equivalent of 160 million pounds.

Projections of cow beef production per head of cattle inventory were multiplied by projections of all cattle inventory to arrive at projections of total cow beef production under each of the two assumptions. The quota formula requires that cow beef production be calculated on a per capita basis, so each of the production projections was divided by projections of U.S. population to arrive at production per capita of inventory (table 3). Then five-year and two-year moving averages were calculated as required in the second term of the formula.

Results

The final results are given in table 4. The trigger level (110% of the base quota) is considered to be the relevant figure since imports generally have been much closer to it than to the base quota. If the cattle inventory growth follows a pattern similar to that in the previous cycle, the trigger level will follow a rather erratic course, with a low point in

1983 (1.33 billion pounds) and a high occuring in 1990 (1.68 billion pounds). The trigger level under the slow inventory growth assumption follows a similar pattern, with lows in the mid-1980s, but reaching a peak of 1.60 billion pounds in 1990 (figure 2). This is because the countercyclical component is relatively insensitive to radical changes in assumptions about herd growth because of the formula's rather long periods of weighted averages—ten years in the denominator of the domestic production part and five years in the cow beef supply numerator portion.

The 1979 law was promulgated through recognition that its predecessor, the 1964 law, allowed imports to increase when domestic production increased, thus exacerbating supply problems. The primary intent in the new law was for the import quota and domestic production to be negatively correlated. In this study a plausible production situation is presented which demonstrates that contrary to the law's intent, the import quota can be positively rather than negatively correlated if herd growth takes place in a manner different from historical conditions. In effect, the formula provides very little systematic countercyclical quota adjustment for a cycle similar to the last one compared to no cycle at all. As a check against the results of the two scenarios, the projections presented in the House of Representatives report 96-238 (U.S. Congress, pp. 8–9) are also given in table 4. These projections follow a similar pattern to those presented in this study, but tend to drop to a lower level (1,240.5 million pounds in 1987) and peak out much higher (1,714.2 million pounds in 1989).

Summary

The major conclusion which can be drawn from this study is that while the so-called U.S. countercyclical meat import bill operates as intended when domestic cattle inventory and production follow a pattern similar to the last cycle, it does not operate in the intended fashion when growth is slower but continuous after 1985. In this case, the 1979 bill operates much the same as the 1964 bill, in which imports and production are positively correlated.

The apparent similarity of trigger levels under the two radically different projections is an indication that, despite beliefs to the contrary, the 1979 bill cannot be considered particularly beneficial or harmful to either the United States or exporting nations. Indeed, it is another example of legislation which was enacted as the result of a felt need but which may operate in a way entirely different from that envisioned by its proponents.

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Demand Elasticities for Soybean Meal in the European Community

Hendrik C. Knipscheer, Lowell D. Hill, and Bruce L. Dixon

Several econometric models have been constructed to describe the demand for soybeans and soybean products (Houck and Mann; Houck, Ryan, and Subotnik; Ryan and Houck 1976a, b; Matthews; Vandenborre 1967, 1970; Jones and Morrison). In most of these studies, the demand for soybeans and soybean products in the European Community (EC) has been included as part of the aggregate world demand for U.S. soybean exports.

Such models provide only limited insight into the effects of policies in subsectors of the world, and their predictive ability is restricted by the underlying assumption of similar demand and supply conditions over geographical regions. Recently, Bredahl, Meyers, and Collins have emphasized the need to disaggregate U.S. export demand into separate geographical markets in order to account for the influence of countries whose internal prices are insulated from world markets.

The Common Agricultural Policy (CAP) of the EC has resulted in demand and supply conditions that differ from those in many other importing countries. Disaggregation of world demand to accommodate separate treatment of EC demand and supply relationships can be justified on the basis of market share and the unique relationships generated by the CAP. The EC is the largest importer of soybeans and soybean meal. Thus, the effects of EC policy changes on the export demand for U.S. soybeans are important. During the period 1971–76, over 25% of the U.S. soybean production (in soybean meal equivalents) entered the EC market. The U.S. share in total EC imports was over 80%, Brazilian exports being the only relevant alternative for EC buyers.

The purpose of this paper is to present a model that describes the demand relationships in the EC so the impact of EC agricultural policies can be estimated. It is confined to the demand for soybean meal in whatever form it first appears in the EC market, as either soybean meal or whole soybeans.

Method of Analysis

In analyzing the soybean market, most observers follow the three-market approach outlined by Houck and Mann, who distinguish markets for soybeans, soybean oil, and soybean meal. The core of their analysis is a multi-equation model of the entire soybean sector. Matthews uses essentially the same model to generate forecasts for the U.S. soybean economy.

Vandenborre's model is also characterized by a system of equations. However, he departs from the three-market approach, observing that "there is no final demand for beans" (Vandenborre 1967, p. 16). He specifies only two export markets: one for oil, shipped in whatever form, and one for meal in whatever form. This study follows the latter approach. By limiting the scope of the study, the econometric model is reduced to a single multiple-regression equation to represent the EC soybean meal market.

The Economic Model

The five goals of the Common Agricultural Policy (CAP) are stated in the Treaty of Rome: (*a*) to increase agricultural productivity, (*b*) to ensure a fair standard of living for the agricultural population, (*c*) to stabilize markets, (*d*) to assure supplies to consumers, and (*e*) to maintain a reasonable price level. The executive branch of the EC, the commission, pursues these objectives by enforcing a set of market price regulations. As a result, prices within the Common Market differ greatly from the world prices, in absolute values as well as relative values. This has had a large impact on the consumption of meat, the composition of the livestock sector, and the use of soybean meal. The divergence between world and domestic prices in the EC requires an economic model disaggregated from world supply and demand relationships.

The following demand model, using semiannual data, was developed to capture the effects of the CAP in conjunction with other components affecting the level of demand:

$$QDSM = f(PSM/PECC, ECPL, APFU, APS, \text{ and } T),$$

where *QDSM* is the quantity of soybean meal de-

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manded, *PSM* is the price of soybean meal, *PECC* is the EC price of cereals, *ECPL* is the EC profitability index for the livestock sector, *APFU* is the animal protein feed units, *APS* is the availability of protein substitutes, and *T* is a time trend.

This model exhibits several special features. The price variable used in the model is the ratio of soybean meal prices to corn prices. Corn price is assumed to capture the variation of all grain prices because the "silo-cathedral" system of the CAP fixes all cereal prices in an essentially constant relationship. The importance of this price ratio has been discussed in previous studies (Houck, Ryan, Subotnik; Womack; Beyer). The profitability index is composed of a weighted ratio of meat price to feedcost. It reflects the effect of the EC meat prices on the demand for soybean meal. This demand shifter was not included in soybean meal demand equations in previous studies, presumably because of the difficulty of collecting the detailed data required for the composition of such an index. To facilitate the derivation of the price elasticity for soybean meal, the inverse of the profitability index is used in estimating the regression coefficients.

Animal protein feed units are used to measure livestock numbers. Most economists have included livestock numbers in models of soybeans and soybean products, but none are very explicit about construction of this variable. Houck and Mann used the intake of protein concentrates per livestock sector as weights for their livestock number index without further explanation or reference. Vandenborre followed the same method, using Landmann's figures for intake of protein concentrates per livestock unit in the dairy and swine sectors. Apparently, he omitted poultry. These can be characterized as behavioral approaches because they are based on feed ratios actually used by farmers in the past. While this is acceptable forecasting, it reduces the explanatory value of the behavioral equation because the farmer's selection of livestock rations is largely explained by his own past feeding practices. Ryan and Houck (1976a) took a more empirical approach, entering swine and poultry numbers as separate variables and disregarding other livestock.

Both the behavioral and empirical approaches have disadvantages which can be partially overcome by the use of animal protein feed units as a measure of livestock demand. Consumption of protein is derived by weighting the output of each sector (milk, meat, and eggs) by specific livestock protein requirements formulated by National Research Council nutritionists. The conversion factors were .420 for poultry meat, .456 for pig meat, .440 for eggs, and .078 for milk. Beef is considered a by-product of the dairy sector and was not explicitly included in the *APFU*. Only milk production in excess of 2,800 kilograms per cow is converted into animal protein feed units. This approach is technical, based on intake requirements, and empirical because it uses output levels. It might miscalculate protein requirements during herd size adjustment periods. However, such adjustments should be reflected in the profitability index.

Protein substitutes (1,000 metric tons [MT] protein equivalents) are limited to the protein concentrates available in the EC market, mainly other oilseed meals and cakes of fishmeal, animal meal, and skimmed milk powder. The inclusion of skimmed milk powder in this variable allows one to trace the effect of the skimmed milk powder surplus on demand for soybean meal. Converting protein substitutes into protein equivalents was done on the basis of the crude protein content of each meal or cake (Houck, Ryan, Subotnik; Beyer; Hoffmeyer et al.). The time trend reflects technological innovation in the livestock sectors and the increase in the average size of livestock holdings.

The Statistical Model

Data are available for each EC country on a weekly, monthly, and/or yearly basis. Hence, an econometric model in which cross-section and time-series data are pooled was used. In such models, assumptions about the variance-covariance matrix of the error terms are crucial. In the soybean meal demand model, the disturbances among the various countries probably are determined by cultural and social factors unique to each country. Data suggest that preferences for various meats differ by country regardless of price relations (Eurostat). Moreover, the collection and classification of data in the EC countries are not yet harmonized. This means that time-series data across countries are not fully comparable. For example, egg prices are collected by numbers (pence per dozen) in the United Kingdom, and by weight (deutsche mark per kg) in Germany.

Differences in meal consumption between time periods are, in part, determined by EC production of hay and forage, which varies mainly because of weather. Although weather effects are partially captured in other independent variables, it can be argued that weather is a major source of variation in the disturbance terms.

Error component models (ECM) and dummy variable models (DVM) can be used for cross-sectional, time-series analysis where some variation in the dependent variable is accounted for by time and cross-sectional differences. Since, ECM has more restrictive assumptions than DVM (see Judge et al.), the latter was used in the analysis. It is possible to have both time and country binary variables, but this would result in thirty-seven binary variables. Instead, the trend variable (T) represents the time effect and gave R^2 values essentially equal to those when time dummies were used. Hence, the final model estimated is

$$QDSM/APFU = \beta_0 + \sum_{i=1}^{6} \beta_i X_i + \beta_7 PSM/PECC + \beta_8 ECPL + \beta_9 APS + \beta_{10} T + u,$$

where the X_i are binary variables to shift the intercept for each country and u is a stochastic error term.

In the model, Belgium and Luxembourg were defined as one economic unit. Data were collected over sixteen years (1961–76) in half-year periods (32 time observations per country). Data for Ireland (a minor meal user) were incomplete, so it was deleted from the analysis, table 1.

Since differences in total soybean meal consumption per country are large, mainly due to country size, the consumption of soybean meal per animal feed unit (*QDSM/APFU*) was taken as the dependent variable. The use of soybean meal consumption per animal protein feed unit implies that the demand elasticity of soybean meal with respect to *APFU* is 1.0. This assumption is acceptable in regions, such as EC, where the size of herds is heavily influenced by government policies.

The estimation results are shown in table 2, which includes the *t*-values associated with the estimated regression coefficients, the relevant elasticities, and the adjusted coefficient of determination.[1]

Estimated Price Elasticity

There are several explanations for the very low value of the price elasticity (−.165) shown in table 2 as compared with other higher estimates (Houck, Ryan, Subotnik; Houck and Mann).[2] First, the presence of a profit variable, not used in the other models, reduced the estimated effects of price changes. The prices of protein concentrates are all interdependent (Beyer). The profitability index, being a ratio of livestock revenue to the cost of feed, is partly dependent on soybean meal prices. Therefore, variation in soybean meal prices will be "picked up" by the price variable and the profit variable. The total price elasticity (e_{total}) is a combination of the calculated price elasticity (e_{price}) and the profit elasticity. It can be shown that the total price elasticity is

$$e_{total} = e_{price} + b_{prof}\left(\frac{W_{pr}\bar{P}_{soy}}{\bar{P}_1 \bar{y}}\right),$$

where b_{prof} is the regression coefficient associated with the inverse of the profitability index, W_{pr} is the quantitative share of protein concentrates in animal feed (28.4% during the period of observation), $\bar{P}_{soy}$ is the average price of soybean meal, $\bar{P}_l$ is an average price index of the livestock sector, and $\bar{y}$ is the mean of the dependent variable (soybean meal consumption per animal protein feed unit).[3] Including the profitability index increases the estimate of the price elasticity to −0.23. This value is still small compared with the elasticities estimated previously.

A second explanation involves the price and income stabilization policy of the EC. Because of the CAP and the high relative prices of feed grains to oilseeds, it is likely that West European compound feed manufacturers and livestock farmers are less sensitive to soybean meal prices than producers elsewhere in the world. A third reason is the rapid expansion of the soybean meal market during the

Table 1. Annual Soybean Meal Consumption per Country in 1,000 MT

	Country							
Year	Germany	France	Italy	Netherlands	Belgium-Luxembourg	United Kingdom	Ireland	Denmark
1961	561	217	161	194	110	287	19	320
1966	1,971	713	547	403	241	441	49	482
1971	2,193	1,313	1,004	1,098	465	524	97	555
1976	2,960	2,115	1,712	1,436	774	985	159	754

Source: FEDIOL.

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[1] The hypothesis that the slope coefficients are constant over countries was tested and rejected. Ordinary least squares applied to individual countries gave generally unsatisfactory results. The results in table 2 probably contain some specification error but are reasonable since the coefficients are of the expected sign, statistically significant, and the $\bar{R}^2$ is high.

[2] The derivation of the price elasticity from the price ratio soybean meal to corn $\left(\frac{PSM}{PECC}\right)$ rather than from the absolute price of soybean meal implies the assumption that the ratio of the means equals the mean of the ratio, i.e.,

$$\frac{\overline{PSM}}{\overline{PECC}} = \overline{\left(\frac{PSM}{PECC}\right)}.$$

During the period of observation, these ratios were within 1% of each other's values.

[3] The inverse of the profitability index (*ECPL*) can be written as

$$ECPL = \frac{W_{pr}P_{soy} + \sum^{k} W_k P_k}{P_l},$$

where W_k is the relative quantity of feedstuff component k ($k \neq pr$), P_k the price of feedstuff component k ($k \neq soy$), and P_l is the price of livestock.

Table 2. Estimated Coefficients and Elasticities for the Dummy Variables Model

	Estimated Regression Coefficient	*t*-values	Derived Elasticity at the Means
PSM/PECC (price)	−0.0746	−2.21	−0.165
ECPL (profit inverse)	−0.5185	−1.91	−0.14
APS (substitutes)	-2.6736×10^{-4}	−1.75	−0.50
T (trend)	0.0302	8.72	0.68

Note: $\bar{R}^2 = 0.85$.

last decade. The continuing expansion shifted the demand curve to the right, causing it to become more inelastic in recent years.

Elasticity of Livestock Profitability

The elasticity of demand for soybean meal with respect to the profitability of livestock production is also very low. The CAP causes profitability variations to remain within rather narrow limits of "fair" income and "fair" consumer prices. The usefulness of pooling cross-section and time-series data is illustrated by the estimation of this regression coefficient. Because the CAP limits the variation of profitability over time, little information about the profit elasticity is obtained from one time period to another. However, since profit levels differ between countries, cross-section data enables an estimate to be made.

Elasticity of Protein Substitutes

The elasticity of demand for soybean meal with respect to the availability of protein substitutes (−.50) compares closely with earlier findings. Houck and Mann estimated an elasticity of about −.45. Vandenborre first estimated this elasticity at −0.38 and later at −0.88. From figures presented by Matthews, it is possible to calculate an elasticity coefficient of −0.7 from his analysis.

During the observation period 1961–76, soybean meal accounted for about 50% of total crude protein in EC concentrates (Vachel). If soybean meal were a perfect substitute for other protein concentrates, a substitution elasticity of −1.0 might have been expected. However the favorable amino acid profile of soybean meal for nonruminants may explain the relatively inelastic estimate for this coefficient (−0.50).

The CAP and the Demand for Soybean Meal

The effects of numerous changes in the EC agricultural policy can be explored with the estimated model. The estimated changes in EC soybean meal demand resulting from three representative CAP changes are shown in table 3.

The effects of cereal price and meat price changes are directly derived from the estimated demand elasticities. The derivation of the effect of surplus skimmed milk powder on the demand for soybean meal warrants further explanation. The average amount of protein substitutes available annually in the EC was 2,739,160 MT protein equivalents. The average annual quantity of skimmed milk powder produced during the study period was 399,820 MT—14.6% of the total substitutes. Consequently, an increase of 10% in the production of skimmed milk powder augments the total amount of substitutes by only 1.46%, implying a 0.7% decrease in soybean meal consumption ($1.46 \times -.50 = -.7$). Therefore, the production of skimmed milk powder could increase 13.7% (+54,800 MT in protein equivalents) before the EC soybean meal demand would decrease by 1% (−26,200 MT protein equivalents). The difference between 54,800 and 26,200 MT protein equivalents demonstrates the efficiency loss in terms of protein utilization. Note, however, that the so-called surplus production of skimmed milk powder (i.e., the amount that is actually "dumped" on the market) is only a small part of total skimmed milk powder production. For that reason, milk powder production in the EC could increase greatly before large negative consequences on demand for soybean meal would be felt, especially since soybean meal is required for the production of milk. Although it is often argued that the production of skimmed milk powder in the EC has a large negative effect on the demand for soybean meal, this study indicates that the effect is small and possibly negligible.

Table 3. Effects of Changes in the CAP on the Yearly Demand for Soybean Meal, 1961–76

	Soybean Meal Demand Changes	
CAP Changes	Relative Change (%)	Absolute Change (1000 MT)
−10% Cereal prices	−2.3	−138
+10% Meat prices	+1.4	+84
+10% Skimmed milk powder production	−0.7	−42

Conclusions

The major conclusions of this study are: (*a*) The Common Agricultural Policy has a significant effect on the demand for soybean meal. Increases in EC grain prices, which are influenced by the CAP, result in an increase in soybean meal demand. Meat prices and skimmed milk powder surpluses affect the EC demand for soybean meal. However, the negative effect of the skimmed milk powder surplus is rather small. (*b*) The price elasticity of the demand for soybean meal is smaller than the price elasticity in the U.S. soybean meal market. This might be caused by the price- and income-stabilizing policy of the EC. The effect of price- and income-stabilizing policies on demand elasticities for farmers' inputs deserves further research. (*c*) Disaggregation of aggregate world demand models into geographical regions with similar agricultural policies affecting prices and quantities of related products can provide useful estimates of the impact of such regional policies.

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Incorporating Technological Change in the Demand for Formula Feed in France

Yves Surry and Karl D. Meilke

> Of the puzzles confronting economists, none is, perhaps, of greater significance than whether the phenomenon of technological change can be abstracted from econometric models. (Renshaw, p. 955)
>
> The use of time trends in economic models is normally regarded as an admission of ignorance. (Deadman and Ghatak, p. 1068)

This paper deals with the issue of incorporating technological change into economic analysis. The problem chosen to illustrate the idea is the demand for formula hog feed in France.

Estimates of formula feed demand play an important part in a more complete model of the French feed concentrate market (Surry). The complete model explains and projects the future demand for soybean meal. This demand depends crucially on the rate of expansion in formula feed use because, in France, most soybean meal is purchased as part of a complete or supplement feed mix. Although only one example is given, the technique seems sufficiently general for use in other situations.

Economic theory suggests that the diffusion of new agricultural technology has changed price levels, efficiency of production, and substitution patterns among commodities. The introduction of least-cost feed mixing, increased awareness of animal nutrition among farmers, vertical integration, and modern merchandising techniques have served to expand the demand for formula feeds. Representing these diverse influences with a simple linear trend is clearly inappropriate because the market for formula feed does not, and can not, expand at a constant rate. However, the differential rate of growth in the formula feed industry can be incorporated in a derived demand function with variational parameter techniques (Maddala). These techniques and their application to the formula feed industry are the subject of this paper.

The Problem

Equation (1) is a typical derived demand function for formula feed,

$$(1)\quad Q_t = A + BY_t + C\frac{PY_t}{PQ_t} + D\ TIME + \mu_t,$$

where Q_t is the demand for formula feed in year t (1,000 MT), Y_t is the production of livestock in year t (1,000 MT carcass weight), PY_t is the price of livestock in year t (francs/MT), PQ_t is the price of formula feed in year t (francs/MT), and *TIME* is a linear trend.[1] A, B, C, and D are parameters to be estimated, and μ_t is a random error term with the normal properties. The factor demand equation specified differs from the usual derived demand function in two respects. First, no substitutes for formula feed have been incorporated in equation (1) and, second, livestock production is considered a fixed factor and acts as a proxy for livestock inventories.

In equation (1), the increasing use of formula feed by farmers is captured by shifting the derived demand curve to the right by D units each year. In reality, however, the adoption of new technology has three possible effects. First, as more and more farmers use formula feed, the quantity used per unit of pork production increases. It approaches the average feed conversion ratio (total feed use per kilogram of pork) as the formula feed market share approaches 100%.[2]

Second, the introduction of formula feed (an essentially new input) changes the pork production function, and these efficiency improvements may cause the average feed conversion ratio to decline over time.

Third, the formula feed price may fall relative to pork price, resulting in increasing feed demand. Clearly, however, any change in relative prices depends on the magnitude of size economies in both

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[1] Data on the price of hogs, price of compound feed, and pork production are from reports of the Institut National de la Statistique et des Etudes Economiques and Foucault. The quantity of formula feed fed to hogs is from the Syndicat National de l'Industrie de l'Alimentation Animale and includes both complete and supplement feeds but excludes premixes. Time in the logistic model equals 1 in 1955, 2 in 1956, etc. In the adaptive varying parameter model, *Time* equals 0 from 1957 through 1964, 1 in 1965, etc. For a more complete description and discussion of the data, see Surry.

[2] The terms "degree of market penetration" and the "market share of formula feed" are used synonymously in this paper; both refer to the quantity of formula feed consumed by hogs divided by the total consumption of concentrates by hogs.

feed manufacturing and pork production, the rate of adoption of new technology in pork production, and the responsiveness of pork prices to supply changes.

Ideally, econometric estimates of the formula feed demand should incorporate all three of the above influences. Equation (1) captures the third influence through the price ratio but does not allow the parameter B to vary as changes occur in the market share of formula feed and the average feed conversion ratio.

A basic question is: What pattern does the "efficiency response" coefficient, B (the marginal formula feed conversion rate), follow during a transition from when very few farmers use formula feed to when nearly all farmers do? Since B is clearly not invariant with respect to time, equation (1) needs to be respecified as follows, with B a time-dependent parameter,

$$(2) \qquad Q_t = A + B_tY_t + C\frac{PY_t}{PQ_t} + \mu_t.$$

If we assume that the adoption of formula feed follows a normal diffusion process (fig. 1a), the degree of market penetration will follow an S-shaped curve (fig. 1b). The increased market share of formula feed will be reflected in the value of B_t (fig. 1c). At the beginning of the transition period, the number of farmers having adopted the new feed input is small, as is the market share of formula feed. It follows that the marginal use of formula feed with respect to total pork production (B_t) is similarly small at $B1$ (fig. 1c). After complete adoption of formula feed, the relationship between formula feed use and pork output reaches a ceiling at ($B1$ + $B2$). This value should reflect the average feed conversion ratio when market penetration is complete. The adoption of formula feed or other technological changes in the pork industry might lower the average feed conversion rate. This can be modelled by making the ceiling level a decreasing function of time.

Although there are many ways to specify change in the parameter B_t, only two are presented—the first uses a logistic varying parameter model and the second uses a modified version of the adaptive regression model (Cooley and Prescott, Rosenberg).

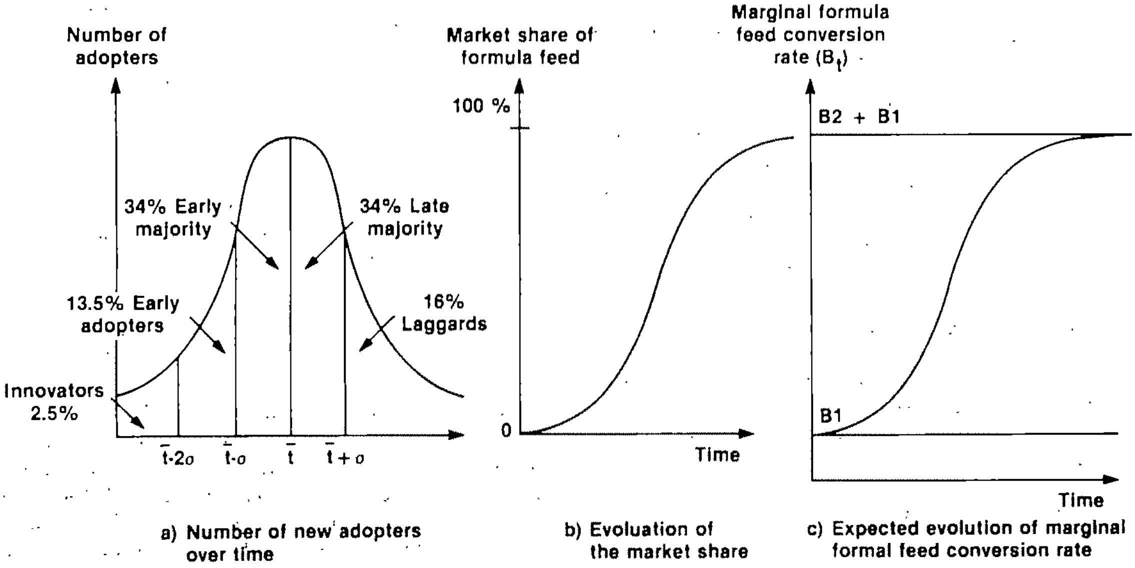
A Logistic Varying Parameter Model

The logistic function provides a good approximation to the S-shaped curve depicted in figure 1c for the efficiency response parameter B_t:

$$(3) \qquad B_t = B1 + \frac{B2}{1 + e^{B3-B4*TIME}} + v_t,$$

where $B1$, $B2$, $B3$, and $B4$ (as positive numbers) determine the shape of the logistic curve, and where $v_t = N(0, \sigma^2_{v_t})$ and COV(μ_t, v_t) = 0.[3]

Substituting equation (3) into equation (2) gives the logistic form of the estimating equation,



a) Number of new adopters over time b) Evoluation of the market share c) Expected evolution of marginal formal feed conversion rate

Figure 1. Normal distribution model of the diffusion process applied to the demand for formula feed

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[3] The sign of $B3$ will depend on the measurement units for the trend, but in our case it is expected to be positive.

$$(4)\quad Q_t = A + C\frac{PY_t}{PQ_t} + B1Y_t + \frac{B2Y_t}{1 + e^{B3-B4*TIME}} + w_t,$$

where $w_t = Y_t v_t + \mu_t$ is a heteroskedastic error term.

The time path of B_t between its minimum and maximum values is determined by the portion of equation (3) defined as X_t,

$$(5)\qquad X_t = \frac{1}{1 + e^{B3-B4*TIME}}.$$

Using (5) and rewriting (3) gives

$$(6)\qquad B_t = B1 + B2X_t + v_t.$$

From (5) and (6) it is clear that as $TIME \rightarrow \infty, X_t \rightarrow 1.0$ and $E(B_t) \rightarrow B1 + B2$, its maximum value. Because the true degree of market penetration by formula feed is unknown, the degree of adjustment in B_t, calculated from (5), is used as a proxy for market share.

Expressions (4), (5), and (6) exhibit several interesting properties. First, following Griliches (p. 504), $B4$ and $B3$ are, respectively, the growth rate or acceptance rate coefficient and the constant of integration positioning the curve on the time scale. Second, as time tends to infinity, the asymptote ($B1 + B2$) is roughly equivalent to the quantity of formula feed needed to produce another unit of pork. Third, the elasticity of feed demand (E_{qy}) with respect to changes in livestock production is

$$(7)\qquad E_{qy} = B_t\frac{Y_t}{Q_t}$$

and should approach one as $TIME \rightarrow \infty$. This is because as long as the market share of formula feed is not 100%, the growth rate in the demand for Q_t will be higher than the rate of growth in pork production. Fourth, the ceiling level may decrease over time because of more efficient animal production techniques. If a linear decreasing trend is assumed, as suggested by Foucault (p. 89), the variation in B_t could be represented by

$$(8)\qquad B_t = B5 + \frac{B6 - B7\ TIME}{1 + e^{B8-B9*TIME}} + v_t,$$

where $B6$ and $B7$ are considered positive.

Rausser and Mundlak have developed procedures to estimate equation (4) correcting for the heteroskedastic error term. However, to simplify the estimation it was assumed that equation (3) is deterministic rather than stochastic. Then the heteroskedastic error term vanishes, and equation (4) can be estimated with nonlinear least squares.

An Adaptive Convergent Parameter Model

In the logistic model, the coefficient B_t varies over time according to a prespecified pattern. Since we know that B_t must reach an upper limit at the completion of the diffusion process, any parameter structure that allows B_t to converge toward an upper limit is an alternative. Rosenberg has developed one such estimator as follows:

$$(9)\qquad B_t = (1 - \lambda)\bar{B} + \lambda B_{t-1} + z_t.$$

In this model, the coefficient λ is an adjustment parameter that must be between zero and one for convergence. It can be seen that for $0 < \lambda < 1$; $B_t \rightarrow \bar{B}$ as $t \rightarrow \infty$. Although this model structure was developed by Rosenberg for cross-section-time-series data, it can be adapted for use with time-series data as shown by Maddala (p. 399).

Using the lag operator (L), the estimatable form of this model is

$$(10)\quad (1 - \lambda L)Q_t = (1 - \lambda)A + (1 - \lambda)\bar{B}Y_t + C(1 - \lambda L)\frac{PY_t}{PQ_t} + (1 - \lambda L)\mu_t + Y_t z_t,$$

which can be rewritten as

$$(11)\quad Q_t = (1 - \lambda)A + (1 - \lambda)\bar{B}Y_t + C\frac{PY_t}{PQ_t} - \lambda C\frac{PY_{t-1}}{PQ_{t-1}} + \lambda Q_{t-1} + \mu_t - \lambda\,\mu_{t-1} + z_t\,Y_t.$$

Hence, the estimatable form of the adaptive model contains lagged dependent and exogenous variables and has a heteroskedastic, autocorrelated error term.

Judge et al. (p. 395) discuss the difficulties of estimating equations similar to (11); but to simplify estimation of equation (11), equation (9) is assumed to be deterministic. In this case equation (9) is a first-order difference equation whose solution is (Yamane, p. 331)

$$(12)\qquad B_t = B_0\lambda^t + \bar{B}(1 - \lambda^t),\ or$$

$$(13)\qquad B_t = B10*e^{t \operatorname{Log}\lambda} + \bar{B},$$

where $B10 = B_0 - \bar{B}$.

Replacing B_t in (2) by (13) gives a demand curve with a well-behaved error term that can be estimated with nonlinear least squares,

$$(14)\qquad Q_t = A + B10\,Y_t e^{t \operatorname{Log}\lambda} + \bar{B}Y_t + C\frac{PY_t}{PQ_t} + \mu_t.$$

From equation (12) it can be seen that the values of the marginal feed conversion ratio (B_t) range from B_0 when $t = 0$ to $\bar{B}$ when $t = \infty$. The transitory values of B_t equal a weighted sum of the two extreme values, with the weights equal to λ^t and $(1 - \lambda^t)$. The weights λ^t and $(1 - \lambda^t)$ represent the proportion of producers who remain to accept, and have accepted, formula feed, respectively. Because $0 < \lambda < 1$, λ^t declines exponentially as $t \rightarrow \infty$. The degree of adjustment of B_t toward $\bar{B}$ is given by

$(1 - \lambda^t)$, which approaches 1.0 as $t \rightarrow \infty$. This value is used as a proxy for the market share of formula feed.

Empirical Results

Table 1 contains various estimates of the demand for pork formula feed in France, where all of the equations have been estimated using annual calendar year data from 1957 through 1977. The table includes estimates of the logistic curve and the adaptive model discussed earlier. For comparison, an equation with no time trend and an equation with a linear time trend estimated both with and without a correction for serial correlation are presented. A comparison of the first four equations in table 1, which employs a constant parameter specification, indicates large parameter variation among equations, strong autocorrelation, and small t-values associated with the price term. The coefficient attached to the livestock production variable ranges from 2.8 in equation (4) to 8.9 in equation (1). Similarly, the price coefficient ranges from −67.9 to 107.0. (The parameter instability is confirmed using the CUSUM test [Brown, Durbin, Evans]). High simple correlation (0.965) between the livestock production variable and the linear time trend likely contributes to this parameter instability. The real problem is caused by our attempt to approximate nonlinear parameter variation with constant parameter techniques. Strong autocorrelation also indicates a possible misspecification of the underlying relationship.

The parameter estimates obtained from the logistic and adaptive models appear more reasonable and, with the exception of the price term, have large t-values associated with them. The low t-value for the price term is not surprising, given the very strong trends in formula feed consumption and pork production. Use of pork production instead of hog inventories in the demand function may also mask some of the price responsiveness of formula feed demand. Changes in the average market weight of hogs are captured in the pork production variable. The price term in the logistic varying parameter equation is the only one with a t-value greater than one. The estimated elasticity is .22 at mean values.

Table 1. Estimates of the Demand for Pork Formula Feed in France

A. Constant parameter without a time trend:

$$Q_t = \underset{(-3.9)^a}{-\,6489.8} + \underset{(11.3)}{8.9}\, Y_t + \underset{(.7)}{107.0}\, PY_t/PQ_t \qquad \text{(OLS)}$$

$\bar{R}^2 = .958$ $DW = 1.15$ $SEE = 298.7$ Obs = 21

$$Q_t = \underset{(.67)}{1645.9} + \underset{(2.81)}{3.5}\, Y_t + \underset{(.63)}{50.2}\, PY_t/PQ_t \qquad \text{(Cochrane-Orcutt)}$$

$\bar{R}^2 = .980$ $DW = 1.68$ Rho = .96 $SEE = 188.1$ Obs = 21

B. Constant parameter with a linear trend:

$$Q_t = \underset{(-1.3)}{-2850.9} + \underset{(2.4)}{4.7}\, Y_t + \underset{(2.3)}{96.4}\, TIME - \underset{(-.4)}{67.9}\, PY_t/PQ_t \qquad \text{(OLS)}$$

$\bar{R}^2 = .966$ $DW = .89$ $SEE = 267.8$ Obs = 21

$$Q_t = \underset{(-2.7)}{-\,3264.3} + \underset{(2.4)}{2.8}\, Y_t + \underset{(5.0)}{186.2}\, TIME + \underset{(.6)}{44.5}\, PY_t/PQ_t \qquad \text{(Cochrane-Orcutt)}$$

$\bar{R}^2 = .988$ $DW = 1.98$ Rho = .76 $SEE = 157.5$ Obs = 21

C. Logistic varying parameter:

$$Q_t = \underset{(-1.5)}{-\,1776.3} + \underset{(2.36)}{2.58}\, Y_t + \underset{(5.45)}{2.48}\, Y_t/[1 + \mathrm{EXP}(\underset{(4.83)}{6.36} - \underset{(-4.99)}{.45}\, TIME)] + \underset{(1.08)}{80.2}\, PY_t/PQ_t$$

$DW = 2.21$ $SEE = 115.9$ Obs = 21

D. Logistic varying parameter with a declining ceiling level:

$$Q_t = \underset{(-.99)}{-\,1127.42} + \underset{(1.59)}{1.83}\, Y_t + (\underset{(1.37)}{7.34} - \underset{(-.93)}{.188}\, TIME)Y_t/[1 + \mathrm{EXP}(\underset{(6.77)}{5.42} - \underset{(-3.95)}{.327}\, TIME)] + \underset{(.72)}{50.83}\, PY_t/PQ_t$$

$DW = 2.54$ $SEE = 109.3$ Obs = 21

E. Adaptive varying parameter:

$$Q_t \doteq \underset{(-1.83)}{-\,2045.4} - \underset{(-5.03)}{2.64}\, Y_t{*}\mathrm{EXP}[TIME{*}\mathrm{Log}(\underset{(3.80)}{.873})] + \underset{(8.2)}{5.83}\, Y_t + \underset{(.73)}{64.0}\, PY_t/PQ_t$$

$DW = 1.41$ $SEE = 160.4$ Obs = 21

[a] t-values are given in parentheses.

Attempts to estimate the adaptive model with parameter variation beginning in 1957 resulted in nonconvergence. Visual inspection of the data clearly suggests that B_t follows an S-shaped time path. Consequently, parameter variation in the adaptive model was started in 1965 because the exponential time path provides a good approximation of the upper half of an S-shaped curve.

Table 2 shows, for both models, the value of B_t, the degree of adjustment in the parameter B_t (a proxy for the market share of formula feed), and the elasticity of feed demand with respect to pork production. For the logistic model, the coefficient increases from 2.64 in 1960 to 5.02 in 1977 as the degree of penetration increases from 2.5% to 98.1%. For the adaptive model, the value of B_t is higher over all of the estimation period, but the differences are not great, particularly during the late 1970s. Over time, the estimated elasticities fall from over 3.0 to just above 1.0 for both models. All of these results appear reasonable based on a priori knowledge.

The elasticity estimates from the traditional model, while approximately the same magnitude early in the period, are far smaller than those from either varying parameter model late in the period. This has obvious implications for future forecasts of the demand for compound feed based on estimates of future growth rates in pork production.

The final equation in table 1 is a logistic varying parameter model corresponding to equation (8), where the ceiling feeding level is allowed to decline over time. While the $TIME^* Y_t$ variable has the expected negative sign, the t-value associated with it is less than one. In addition, the value on the efficiency response coefficient early in the period seems unrealistically large, and the value late in the period is unrealistically small.

Summary and Conclusions

The two varying parameter models used in this paper illustrate a way to introduce technological diffusion processes into econometric relationships. In particular, the logistic model performs well, having the smallest standard error of estimate while approximating the expected time path of the efficiency response parameter. This model is, however, most useful when the diffusion process is nearly complete or when the penetration rate can be estimated directly. Both of the varying parameter models can be estimated easily and inexpensively with any nonlinear regression package, as long as the parameter variation is deterministic. Both varying parameter models generate elasticity estimates consistent with a priori expectations, whereas the elasticity estimates from the fixed parameter models are far smaller than expected at the end of the estimation period.

The relationship between livestock production and formula feed use is crucial in projecting the demand for formula feed and formula feed ingredients such as soybean meal. Consequently, the method developed here to account for technological change in animal feeding should provide improved forecasts of future feed ingredient demand in countries where the use of formula feed has grown rapidly.

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Table 2. Estimated Values of Efficiency Response Coefficients, Market Share, and Elasticity

	Logistic Model			Adaptive Model			Model with Time Variable (Cochrane-Orcutt)
	B_t Estimated Coefficients	Market Share Proxy	E_{qy}[a] Elasticity	B_t Estimated Coefficients	Market Share Proxy	E_{qy} Elasticity	E_{qy} Elasticity
1960	2.64	0.025	3.18	3.20	0.0	3.22	3.14
1965	3.07	0.196	1.90	3.54	.126	2.17	1.99
1968	3.78	0.482	1.81	4.00	.416	1.60	1.16
1972	4.69	0.849	1.37	4.77	.662	1.40	0.86
1977	5.02	0.981	1.32	5.30	.828	1.34	0.75
Asymptote	5.07			5.85			
λ				0.87			

[a] E_{qy} is elasticity of formula feed demand with respect to livestock production.

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Rational Expectations in Agricultural Economics Research and Policy Analysis

Brian S. Fisher

Despite recognition by agricultural economists that price expectations are important in agricultural decision making, few changes in the way price expectations appear in economic models of agriculture have been made during the past two decades. For example, in the major proportion of existing supply response studies it has been assumed that price expectations are formed adaptively. (For an illustration of the extent that this assumption has been used, see Askari and Cummings.) That is, expected price is assumed to be a weighted average of past prices with the weights declining geometrically over time. In other supply response studies, it is assumed that a polynomial distributed lag on product prices provides an adequate representation of the system's dynamic structure (see, for example, Meilke, Zwart, Martin; or Fisher). However, as Muth (p. 315) noted, there is "little evidence to suggest that the presumed relations bear a resemblance to the way the economy works."

Although data on anticipations are collected in many ways, only a few studies have tried to determine how individual decision makers actually form expectations (Heady and Kaldor, Turnovsky, and Fisher and Tanner). Katona, in calling for more research of this kind, also identifies some difficulties in studying the psychology of individuals' learning processes. Until psychologists make more progress in this area, economists who incorporate anticipations in their models will have to use another approach. However, there are few choices.

The popular adaptive expectations hypothesis is inadequate, not because it implies that the forecast of a particular variable is a distributed lag of its own past values, but because it implies that the distributed lag parameters are restricted in an ad hoc way. In general, assuming that price expectations are formed adaptively is ad hoc because the parameter restrictions in the distributed lag are not the result of an optimization process. Alternative formulations, such as the assumption that expectations are naive or generated by some other simple autoregressive form, are inadequate for similar reasons.

The Rational Expectations Hypothesis

These problems can be partly overcome by assuming that expectations are rational. The concept of rational expectations provides a method of interpreting agents' (decision makers) use of available information in making decisions. Rational expectations for a particular variable are mathematical expectations conditional on available information. This information consists of all available observations on the variable in question and on related variables at the time the forecast is made. According to Muth, "Expectations, since they are informed predictions of future events, are essentially the same as the predictions of the relevant economic theory" (p. 316).

The rational expectations hypothesis implies that agents know the structure of the system in which they operate. To use Sims' (p. 6) example, it is possible that on reading news of a frost in Brazil, U.S. consumers will stockpile coffee in anticipation of a price increase. The implication is that variables known to affect supply enter the demand equation (and vice versa) through their effect on expected price. Therefore, the optimal price predictor will contain information from both the supply and demand equations. Thus, an unrestricted adaptive expectations formulation is not optimal. (For a simple model, Muth [p. 320] illustrates the relationship between the rationally expected price and a restricted geometrically weighted average of past prices. In this case, the coefficient in the expectations formula is a function of the original demand and supply parameters.)

To solve a microeconomic problem, such as a firm's supply response, neoclassical economists often postulate a representative firm maximizing some constrained objective function. To many agricultural economists, this suggests standard mathematical programming. The rational expectations framework, however, provides a systematic way to incorporate the effects of uncertainty about future prices. Typically, this involves assuming that the agent wishes to maximize discounted expected profit subject to technological constraints. Further assumptions, such as restricting the returns function to be linear quadratic, are used to make the control problem mathematically tractable. The solutions generate a set of equilibrium stochastic processes, some of which describe the representative firm's optimal decision rules such as investment or

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supply equations. An equilibrium that satisfies the constraints of the stochastic optimization problem is known as a rational expectations equilibrium because the representative firm is assumed to forecast particular variables by taking conditional mathematical expectations using the stochastic processes actually governing those variables (Sargent 1979, pp. 342–3). The final estimating equations include nonlinear cross-equation restrictions on the parameters. Extensive work has been done on both the formulation and estimation of this model type (Hansen and Sargent; Sargent 1979, 1981; Nerlove, Grether, Carvalho; Eckstein).

Alternatively, Wallis and McCallum (1976) have imposed rational expectations on a classical econometric model in which expected values of a subset of the endogenous variables are included in the system. In this case, it is implicit that the equations in the system describe both the optimal decision rules of the agents and the way they interact with each other. Using decision rules of traditional econometric models loses some of the structure derived by solving an optimization problem. Therefore, applying rational expectations to an already established econometric model is less useful than starting from first principles. However, it does allow the analyst to employ restrictions from economic theory in taking account of unobservable anticipations variables. This is more consistent with the notion that economic agents are optimizers than using typical ad hoc formulations.

The Lucas Critique

The expected price formulation adopted also should allow for changes in government policy. For example, it is naive to build supply response models containing price expectations generated by past prices alone when a government agency is known to be altering the future course of prices. This is extra information that can be used to make more informed price forcasts. To employ devices such as simple adaptive expectations is to ignore this information.

Basically, this is the criticism raised by the "rational expectations school" about how traditional economic models have been used to evaluate the impact of changes in government policy. Here, the emphasis is on changes in the policy rules or regime rather than the value of some specific policy instrument. The "rational expectations school" argues that the parameters of the decision rules are functions not only of parameters in agents' objective functions and the stochastic processes that generate the exogenous variables but are also functions of government policies. The latter affect the paths of those exogenous variables considered to be policy instruments. If so, the estimated coefficients of most economic models are not invariant to changes in policy regimes. If economists wish to analyze policy interventions, such as price stabilization schemes or changes in target price formulas, then it is necessary to identify how policy regime changes alter the basic model. This says that economic agents perceive the type of policy being followed and take that information into account when forming expectations. These issues, first raised by Lucas in a macroeconomic context, have been labelled as the Lucas critique in the general macroeconomic literature. (For a discussion of these questions using a model of investment under uncertainty, see Sargent 1981, pp. 231–4).

If a change in the policy regime may affect a theoretical model's parameters, then the economist should build an empirical model that will allow inferences to be drawn about how agents will behave as their environment changes. Often, the change in environment is really a change in one constraint in the agents' decision-making problem. Therefore, to analyze a policy change, it is necessary to trace the effect of a change in a constraint through to the relevant decision rule (Lucas and Sargent). If economists accept that economic agents are rational in the sense that they are optimizers (a readily accepted view in both firm and demand theory), then the rational expectations hypothesis provides a framework to solve this crucial problem.

Rational Expectations in a Simultaneous Equations Framework

This is an illustration of how the rational expectations hypothesis can be imposed on a traditional simultaneous equations model. It explores, through example, the impact of a policy rule change on the model. This approach is similar to Wallis' (pp. 50–52).

Consider the general model,

$$\mathbf{B}\mathbf{y}_t + \mathbf{A}\mathbf{y}^*_t + \mathbf{\Gamma}_1\mathbf{x}_{1t} + \mathbf{\Gamma}_2\mathbf{x}_{2t} = \mathbf{u}_t, \tag{1}$$

where $\mathbf{y}_t$ is a vector of g endogenous variables, $\mathbf{y}^*_t$ is a vector of g anticipations formed in period $(t - 1)$ on the endogenous variables, $\mathbf{x}_{1t}$ is a k_1 vector of exogenous variables, $\mathbf{x}_{2t}$ is a $(k - k_1)$ vector of intercept and seasonal terms whose future values are known with certainty. For simplicity, assume that there are no lagged endogenous variables in the system. The parameter matrices $\mathbf{B}$, $\mathbf{A}$, $\mathbf{\Gamma}_1$, and $\mathbf{\Gamma}_2$ have dimensions $(g \times g)$, $(g \times g)$, $(g \times k_1)$, and $[g \times (k - k_1)]$, respectively. A necessary condition for identification in this system is that there are more exogenous variables than anticipations variables (Wallis, p. 63).

The expectations variables, $\mathbf{y}^*_t$, are unobservable. Therefore, it is necessary to make some assumptions about the formation of expectations before the system's parameters can be estimated. For example, if agents form naive expectations, then $\mathbf{y}^*_t = \mathbf{y}_{t-1}$. However, if the rational expectations hypothesis is imposed, then expectations are the same as the predictions from the model, conditional on the information available, Ω_{t-1}. That is equivalent to defining $\mathbf{y}^*_t$ as $\mathbf{y}^*_t = E\ (\mathbf{y}_t|\Omega_{t-1})$.

From (1) note that

$$\mathbf{B}\mathbf{y}_t + \mathbf{A}\mathbf{y}^*_t = \mathbf{u}_t - \Gamma_1\mathbf{x}_{1t} - \Gamma_2\mathbf{x}_{2t}. \tag{2}$$

Taking conditional expectations gives

$$E\ (\mathbf{B}\mathbf{y}_t + \mathbf{A}\ \mathbf{y}^*_t) = E\ (\mathbf{u}_t - \Gamma_1\mathbf{x}_{1t} - \Gamma_2\mathbf{x}_{2t}), \tag{3}$$

and, therefore,

$$(\mathbf{B} + \mathbf{A})\ \mathbf{y}^*_t = -\Gamma_1\hat{\mathbf{x}}_{1t} - \Gamma_2\mathbf{x}_{2t}, \tag{4}$$

where $\hat{\mathbf{x}}_{1t}$ are the predictions of the exogenous variables in period (t), given all information available up to period $(t - 1)$. The vector of expectations, $\mathbf{y}^*_t$, is then

$$\mathbf{y}^*_t = -(\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_1\hat{\mathbf{x}}_{1t} - (\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_2\mathbf{x}_{2t}. \tag{5}$$

Substituting (5) into (1) expresses the model in terms of observable variables:

$$\begin{aligned}\mathbf{B}y_t - \mathbf{A}(\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_1\hat{\mathbf{x}}_{1t} \\ + \Gamma_1\mathbf{x}_{1t} - \mathbf{A}(\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_2\mathbf{x}_{2t} \\ + \Gamma_2\mathbf{x}_{2t} = \mathbf{u}_t.\end{aligned} \tag{6}$$

The restrictions inherent in equation (6) imply that the information useful in forecasting shifts in the exogenous variables is incorporated in the model consistent with the economic structure underlying equation (1).

The reduced form of the system then becomes

$$\begin{aligned}\mathbf{y}_t = \mathbf{B}^{-1}\ \mathbf{A}(\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_1\hat{\mathbf{x}}_{1t} \\ - \mathbf{B}^{-1}\ \Gamma_1\mathbf{x}_{1t} + \mathbf{B}^{-1}\ \mathbf{A}(\mathbf{B} + \mathbf{A})^{-1}\ \Gamma_2\mathbf{x}_{2t} \\ -\mathbf{B}^{-1}\ \Gamma_2\mathbf{x}_{2t} + \mathbf{B}^{-1}\ \mathbf{u}_t.\end{aligned} \tag{7}$$

The errors in rational expectations are the differences between $\mathbf{y}_t$ and $\mathbf{y}^*_t$. Subtracting (5) from (7) gives[1]

$$\mathbf{y}_t - \mathbf{y}^*_t = \mathbf{B}^{-1}\ \Gamma_1\ (\hat{\mathbf{x}}_{1t} - \mathbf{x}_{1t}) + \mathbf{B}^{-1}\ \mathbf{u}_t. \tag{8}$$

To complete the model, it is necessary to specify forecasting functions for the $\hat{\mathbf{x}}_{1t}$ variables. This might be done by specifying a vector autoregressive moving-average model for $\mathbf{x}_{1t}$. A very simple model of this form is the first-order autoregressive model,

$$\mathbf{x}_{1t} = \Phi\mathbf{x}_{1t-1} + \epsilon_t, \tag{9}$$

where ϵ_t is a white noise process independent of the disturbance, $\mathbf{u}_t$. In this case $\hat{\mathbf{x}}_{1t} = \Phi\mathbf{x}_{1t-1}$ because $E(\mathbf{x}_{1t}|\Omega_{t-1}) = \Phi\mathbf{x}_{1t-1}$. The set of equations to be estimated is then represented by (6) and (9). Wallis (pp. 64–69) discusses some ways that such a system could be estimated.

Although lagged endogenous variables can be incorporated in the Wallis framework, the sources of the lags are usually not identified as explicitly in traditional econometric models as in models built using the Hansen and Sargent approach. Production restrictions and adjustment processes are incorporated as constraints in the optimization problem when the Hansen and Sargent approach is adopted. A result is that distributed lags in the final estimating equations have a stronger theoretical underpinning than data-based distributed lags featured in many econometric models. This and the differences in treating disturbance terms are the major dissimilarities between the Wallis and Hansen and Sargent approaches.

An Illustration

Consider the following simple supply and demand model for an agricultural commodity:

$$\begin{aligned}Q_t \quad + \alpha_{12}P^*_t + \gamma_{11}PI_t - \gamma_{11}S_t \\ + \gamma_{13} = u_{1t}\ \text{(supply)},\end{aligned} \tag{10}$$

$$\beta_{21}\ Q_t + P_t \quad + \gamma_{22}\ Y_t + \gamma_{23} = u_{2t}\ \text{(demand)}. \tag{11}$$

The quantity supplied Q_t, is a function of the price expected in period (t), P^*_t, the price of inputs, PI_t, and the value of an input subsidy (or tax), S_t. In this case, S_t may represent a subsidy paid on fertilizer price, or it could represent an excise tax on fuel prices. The coefficient on the variables PI_t and S_t is the same because the sum of these variables is the total price paid for inputs. Equation (11) is the price (demand) equation. Price, P_t, is specified as a function of the quantity sold and disposable income, Y_t. The system is recursive and the market clears in each period.

The rational expectations hypothesis implies that, when forming expectations, farmers take account of both supply and demand factors. In the present case, rational farmers will take account of how the income variable, Y_t, is changing, as well as how PI_t and S_t are changing. The matrices corresponding to the format of equation (1) are

$$\mathbf{B} = \begin{bmatrix} 1 & 0 \\ \beta_{21} & 1 \end{bmatrix} \qquad \mathbf{A} = \begin{bmatrix} 0 & \alpha_{12} \\ 0 & 0 \end{bmatrix}$$

$$\Gamma_1 = \begin{bmatrix} \gamma_{11} & -\gamma_{11} & 0 \\ 0 & 0 & \gamma_{22} \end{bmatrix} \quad \Gamma_2 = \begin{bmatrix} \gamma_{13} \\ \gamma_{23} \end{bmatrix}$$

$$\mathbf{y} = [Q_t\ P_t]' \qquad \mathbf{y}^* = [Q^*_t\ P^*_t]'$$

$$\mathbf{x}_1 = [PI_t\ S_t\ Y_t]'$$

and $\mathbf{x}'_2$ is the unit vector.

From (6), the model, in observable variables, is

$$\begin{aligned}Q_t + \frac{\alpha_{12}\ \beta_{21}\ \gamma_{11}}{\omega}\ \widehat{PI}_t - \frac{\alpha_{12}\ \beta_{21}\ \gamma_{11}}{\omega}\ \hat{S}_t \\ - \frac{\alpha_{12}\ \gamma_{22}}{\omega}\ \hat{Y}_t + \gamma_{11}PI_t - \gamma_{11}S_t + \gamma_{13} \\ + \frac{\alpha_{12}\ \beta_{21}\ \gamma_{13} - \alpha_{12}\ \gamma_{23}}{\omega} = u_{1t},\end{aligned} \tag{12}$$

---

[1] The source of the errors in anticipations can be seen by inspection of equation (8). These errors are a function of the deviations of the actual values of the exogenous variables from their expected values and the disturbances of the economic model. Contrary to the views expressed by some (for example, see Forman), it is obvious from (8) that the rational expectations hypothesis does not imply that agents in the economic system have perfect foresight.

$$(13) \qquad \beta_{21} Q_t + P_t + \gamma_{22} Y_t + \gamma_{23} = u_{2t},$$

where $\omega = 1 - \beta_{21}\alpha_{12}$.

Notice that the supply equation contains anticipated values for the exogenous variable from the demand equation and that there are nonlinear cross-equation restrictions on the supply equation parameters. There are no such restrictions on the demand equation, (13), because there are no expectations variables in equation (11). The restrictions that result from the rational expectations hypothesis provide information that can be used to identify α_{12} and β_{21}. Although statistically consistent estimates of the parameters can be obtained without the restrictions, imposing the cross-equation restrictions during estimation will result in more efficient estimates of the parameters in the system than otherwise would be the case. For a given data set, the null hypothesis that there are no parameter restrictions can be tested against the alternative that the rational expectations restrictions hold (Hoffman and Schmidt).

The reduced form of the system can be written using (7):

$$\begin{aligned}(14) \quad Q_t = {} & \frac{-\alpha_{12}\,\beta_{21}\,\gamma_{11}}{\omega}\,\widehat{PI}_t + \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}}{\omega}\,\hat{S}_t \\ & + \frac{\alpha_{12}\,\gamma_{22}}{\omega}\,\hat{Y}_t - \gamma_{11}\,PI_t + \gamma_{11}\,S_t \\ & + \left[\left(\frac{\alpha_{12}\,\gamma_{23} - \alpha_{12}\,\beta_{21}\,\gamma_{13}}{\omega}\right) - \gamma_{13}\right] + v_{1t},\end{aligned}$$

$$\begin{aligned}(15) \quad P_t = {} & \frac{\beta_{21}{}^2\,\alpha_{12}\,\gamma_{11}}{\omega}\,\widehat{PI}_t - \frac{\beta_{21}{}^2\,\alpha_{12}\,\gamma_{11}}{\omega}\,\hat{S}_t \\ & - \frac{\beta_{21}\,\alpha_{12}\,\gamma_{22}}{\omega}\,\hat{Y}_t + \beta_{21}\,\gamma_{11}\,PI_t - \beta_{21}\,\gamma_{11}\,S_t \\ & - \gamma_{22}\,Y_t + \left[\left(\frac{\beta_{21}{}^2\,\alpha_{12}\,\gamma_{13} - \beta_{21}\,\alpha_{12}\,\gamma_{23}}{\omega}\right)\right. \\ & \left. + \beta_{21}\,\gamma_{13} - \gamma_{23}\right] + v_{2t},\end{aligned}$$

where $\mathbf{v}_t$ is a matrix of reduced-form disturbances. Before the model can be estimated, the stochastic processes that are to be used to forecast future values of the exogenous variables must be specified. With estimates of the model parameters, equations (14) and (15) can be used for forecasting or policy analysis.

The policy variable, S_t, is a subsidy paid on inputs. The aim is to analyze the impact on output of a change in the subsidy. Assume that the process which generates S_t can be written

$$(16) \qquad S_t = \phi_1 S_{t-1} + \epsilon_{1t}.$$

The optimal forecasting equation for quantity is then obtained by substituting the forecast, $\hat{S}_t = \phi_1 S_{t-1}$, into (14) together with the forecasting equations for $\widehat{PI}_t$ and $\hat{Y}_t$. If the stochastic processes underlying PI_t and Y_t were

$$(17) \qquad PI_t = \phi_2 PI_{t-1} + \phi_3 PI_{t-2} + \epsilon_{2t},$$

$$(18) \qquad Y_t = \phi_4 Y_{t-1} + \epsilon_{3t},$$

then the optimal forecasting equation for quantity would be

$$\begin{aligned}(19) \quad Q_t = {} & -\gamma_{11}\,PI_t - \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\phi_2}{\omega}\,PI_{t-1} \\ & - \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\phi_3}{\omega}\,PI_{t-2} + \gamma_{11} S_t \\ & + \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\phi_1}{\omega}\,S_{t-1} + \frac{\alpha_{12}\,\gamma_{22}\,\phi_4}{\omega}\,Y_{t-1} \\ & + \frac{\alpha_{12}\,\gamma_{23} - \alpha_{12}\,\beta_{21}\,\gamma_{13}}{\omega} - \gamma_{13} + v_{1t}.\end{aligned}$$

Equation (19) shows that the rational expectations hypothesis provides a reduced form similar to other distributed lag reduced forms except for the parameter restrictions on the distributed lags.

The impact of unannounced changes in S_t on the quantity produced will be given by the coefficient γ_{11}, since the change in $\hat{S}_t$ is zero. This is similar to the usual impact multiplier analysis. However, this is not a particularly interesting case because most agricultural policy is not conducted in stealth. Therefore, consider the case where the government announces that, because of budgetary constraints, it can no longer pay the subsidy, and that it intends to phase out the subsidy evenly over a four-year period. The usual approach to assessing the impact of such an announcement on quantity produced in the period immediately following it would be to change the level of S_t by 25% and to calculate the impact on Q_t. However, if the government has announced that it intends to phase out the subsidy evenly, then the process generating S_t has changed. The new process could be written as[2]

$$(20) \quad S_t = \begin{cases} S_{t-1} - .25\,\bar{S}, & \text{for the first four years,} \\ 0, & \text{after four years,} \end{cases}$$

where $\bar{S}$ is the initial subsidy level. Substituting the optimal predictor of S_t, $\hat{S}_t = S_{t-1} - 0.25\,\bar{S}$, into (14), together with the forecasting equations for PI_t and Y_t results in the following equation:

$$\begin{aligned}(21) \quad Q_t = {} & -\gamma_{11} PI_t - \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\phi_2}{\omega}\,PI_{t-1} \\ & - \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\phi_3}{\omega}\,PI_{t-2} + \gamma_{11} S_t \\ & + \frac{\alpha_{12}\,\beta_{21}\,\gamma_{11}}{\omega}\,S_{t-1} + \frac{\alpha_{12}\,\gamma_{22}\,\phi_4}{\omega}\,Y_{t-1} \\ & + \left[\left(\frac{\alpha_{12}\,\gamma_{23} - \alpha_{12}\,\beta_{21}\,\gamma_{13}}{\omega}\right) - \gamma_{13}\right. \\ & \left. - \left(\frac{.25\alpha_{12}\,\beta_{21}\,\gamma_{11}\,\bar{S}}{\omega}\right)\right] + v_{3t}.\end{aligned}$$

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[2] An alternative specification for the policy change would be to consider ϕ_1 in equation (16) as a time-varying coefficient with values 0.75, 0.66, 0.5, 0, 0, 0. . . . in the years after the change.

Comparing equations (19) and (21) shows that some of the reduced-form parameters have changed. In this case, the impact of the change in the policy regime is given by the change in the coefficient on S_{t-1}, the altered intercept term, and the change in the subsidy variable itself. The outcome is obviously different from that calculated in the traditional way. It is not uncommon for analysts to change intercept terms in equations of traditional econometric models in order to simulate the effects of policy changes. However, this is not an adequate substitute for a fully specified rational expectations model because this hypothesis has implications not only for the way in which the system is estimated, but also for how it is simulated.

An Overview

The Lucas criticism of the conventional use of econometric models for either *ex ante* or *ex post* analysis of changes in policy rules has been demonstrated with a simple model of a commodity market. If economic agents possess information about a forthcoming change in the policy regime and they use that information in an optimal way, then reliance on a traditional simulation approach will lead to incorrect conclusions about its effects. The reason is that the parameters of the system will change given nontrivial policy changes. However, if the model is specified so that the user can incorporate a new process to describe the path of the policy instrument after a change, then the simulation remains valid. As pointed out by Wallis, "The difficulty in the usual approach is that data-based distributed lags confuse two separate aspects, namely economic optimization procedures and forecasting procedures, and the effect of a required change in the latter on the lag function cannot be perceived without separating the two components" (p. 71).

It has been demonstrated that the rational expectations framework provides a way to overcome the Lucas criticism of the traditional method of policy evaluation. However, there are some objections to the rational expectations hypothesis. According to McCallum (1980, p. 38), there are two common criticisms of the hypothesis. First, it may be unrealistic to assume that agents use all information that is available. Second, it may be unrealistic to assume that agents use information as intelligently as the hypothesis claims. Two other criticisms are that it is unrealistic to assume that agents know with certainty the processes which generate the exogenous variables, and that the existence of commodity cycles is inconsistent with the notion of rational expectations. The first and third are criticisms of the simplifying assumptions that information is costless and that there is instantaneous learning by agents. As in any economic model, these assumptions are made so that approximate solutions to some practical problems can be obtained. Extension of the model to incorporate effects of the cost of information is consistent with the framework already established by Sargent and others. Attempts to incorporate learning in models, however, are likely to be different (Sargent 1981, pp. 234–6; De Canio; Grossman).

The final criticism is unfounded. Typically rational expectations models contain lags due to cost-of-adjustment effects and technological constraints. Simulation of the resulting stochastic linear difference equations will, under some circumstances, generate cycles (Sargent 1979). The second criticism of the rational expectations hypothesis is genuine. However, the rational expectations hypothesis is consistent with the common notion that economic agents are optimizers, and it generates readily testable propositions. It remains for agricultural economists to test them.

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Rational Expectations and Competitive Pricing and Storage

Peter G. Helmberger, Robert D. Weaver, and Kathleen T. Haygood

Should the government of a free enterprise economy such as the United States undertake commodity price stabilization? Economists can surely help to answer this question by measuring the economic effects of whatever stabilization program is under consideration. If benefit and cost measurements can be made, so much the better. Quantitative analysis is needed on the performance of commodity markets over time with and without a stabilization program.

At present such analysis is impeded by the absence of a satisfactory intertemporal theory of market storage and pricing under conditions of uncertainty. Literature in the Waugh-Oi tradition, including papers by Massell (1969, 1970), Turnovsky, and Subotnik and Houck, is concerned mainly with the benefits and costs of stabilization in comparison with markets where the role of market storage is ignored. Another line of work, following Gustafson, seeks to determine optimum storage given initial conditions, including carryin from previous periods and demand and supply relationships. Here, too, the role of a market or other allocative mechanism in determining storage levels often is given short shrift. The recent paper by Burt, Koo, and Dudley, for example, estimates optimal strategies for a U.S. wheat reserve policy without modeling private storage decisions and without analyzing interactions between private and public decision makers. While this approach may be useful in identifying inefficiency, it is not clear how, in a market economy, such findings can be used to frame a sensible government program. A third area of relevant literature deals with futures markets. Although this literature is vast and instructive (Gray and Rutledge), the theoretical work is often informal and disjointed.

The objective of this paper is to develop a theory of competitive pricing and storage under uncertainty. We believe that the theoretical results have important implications for future empirical research and public policy. This development draws upon the earlier work of Samuelson, Turnovsky, and Helmberger and Weaver. Samuelson developed a theory of storage and temporal pricing assuming that future events were known with certainty. He suggested that his theory might help in understanding real-world phenomena and be a stepping stone to analyses involving uncertainty. When uncertainty is introduced, however, an assumption must be made about how price expectations are formed by market participants. Helmberger and Weaver developed a theory of storage under conditions of uncertainty assuming that producers and arbitragers are guided by rational expectations (Muth). However, the way price expectations are formed within their theory is consistent with rational expectations only under restrictive assumptions, and one purpose of this paper is to relax those assumptions.

A Theory of Competitive Pricing and Storage under Uncertainty

We postulate the following model:

$$D_t = \alpha_0 - \alpha_1 P_t + U_t, \tag{1}$$

$$S_t = \beta_0 + \beta_1 E_{t-1}(P_t) + V_t, \tag{2}$$

$$D_t - S_t - I_{t-1} + I_t = 0, \tag{3}$$

where D_t, S_t, and P_t are, respectively, quantity demanded for consumption, quantity supplied, and price in period t. The carryout and carryin are given by I_t and I_{t-1}, respectively. $E_{t-1}(P_t)$ is the expected price in period t formed at the end of period $t - 1$. U_t and V_t are random variables with zero means and finite variances. Randomness in demand is unrelated to randomness in supply, so that $E_{t-1}(U_tV_t) = 0$.

We want to explain how prices, inventories, quantities consumed, and quantities produced are determined, given initial conditions, for a set of time dated markets $t, t + 1, \ldots, t + h$, where the period $t + h$ is the horizon beyond which expectations are not formed. A number of assumptions are made to simplify the analysis. The following theoretical development is limited to a two-period case with the terminal condition, $I_{t+1} = 0$. However, an algorithm is briefly described for solving models with horizons extending beyond two periods. A zero discount rate is assumed, although a generalization with a nonnegative discount rate is conceptually straightforward. We also assume that storage is a constant cost industry, and we abstract from convenience yields associated with stockhold-

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ing. Intertemporal arbitragers seek to maximize expected profit and are risk neutral.[1] They may, therefore, be expected to store in such quantity as to drive their expected profits to zero. The following familiar conditions emerge:

$$(4)\qquad E_t(P_{t+1}|I_t > 0) = P_t + T,$$
$$(5)\qquad E_t(P_{t+1}|I_t = 0) \leq P_t + T,$$

where T equals the constant average cost of storage. Equations (1)–(5) form the equilibrium system to be analyzed. They define two distinct ways in which P_t may be determined.

We assume that all expectations, whenever formed, are rational in the sense of Muth. Since the carryout from period t may be zero or positive, the expected price in period t, formed at $t - 1$, may be expressed in probabilities and conditional expectations as follows:

(6)
$$E_{t-1}(P_t) = pE_{t-1}(P_t|I_t = 0) + (1 - p)E_{t-1}(P_t|I_t > 0),$$

where p is the probability that I_t equals zero. To see the economic significance of (6), define $Z_t = U_t - V_t$. For sufficiently large values of Z_t, demand is great relative to supply. Storage does not occur, and price and output in period t are determined by production and demand. Under these circumstances, $I_t = 0$, and the tth market is not linked to future markets. Alternatively, for sufficiently small values of Z_t, demand is weak relative to supply. Storage occurs, and price, consumption, and carryout in period t are determined not only by production and the demand for immediate consumption but also by the arbitragers' demand for storage. We postulate a critical value for Z_t, Z_{tc}, such that for $Z_t \geq Z_{tc}$, $I_t = 0$ and for $Z_t < Z_{tc}$, $I_t > 0$. An algebraic expression for Z_{tc} will be developed later. The probabilities appearing in equation (6) are functions of Z_{tc}. Specifically,

$$p = \int_{Z_{tc}}^{\infty} f(Z_t)dZ_t,$$

where $f(Z_t)$ is the probability density function for Z_t. In what follows we use conditional expectations defined as

$$E_{t-1}(Z_t|Z_t \geq Z_{tc}) = \left[\int_{Z_{tc}}^{\infty} Z_t f(Z_t)dZ_t\right]/p$$

$$E_{t-1}(Z_t|Z_t < Z_{tc}) = \left[\int_{-\infty}^{Z_{tc}} Z_t f(Z_t)sZ_t\right]/(1 - p).$$

Two alternative structural models are implicit in the above system. One is when $Z_t \geq Z_{tc}$; the other is when $Z_t < Z_{tc}$. Each of these models is analyzed separately. Then they are joined together with equation (6).

The Case of Zero Carryout from Period t

If $Z_t \geq Z_{tc}$, then $I_t = 0$ and price in period t is determined by production and the demand for consumption. We use equations (1)–(3) to solve for P_t and then find the appropriate conditional expectation of P_t. This yields

$$(7)\qquad P_t = \frac{1}{\alpha_1}[\alpha_0 - \beta_0 - \beta_1 E_{t-1}(P_t) - I_{t-1} + Z_t],$$

$$(8)\qquad E_{t-1}(P_t|Z_t \geq Z_{tc}) = \frac{1}{\alpha_1}[\alpha_0 - \beta_0 - \beta_1 E_{t-1}(P_t) - I_{t-1} + E_{t-1}(Z_t|Z_t \geq Z_{tc})].$$

Note that $E_{t-1}(P_t|Z_t \geq Z_{tc})$ equals $E_{t-1}(P_t|I_t = 0)$, as shown on the right-hand side of equation (6).

Turn next to period $t + 1$, noting that $I_t = I_{t+1} = 0$. Therefore, (3) reduces to $D_{t+1} = S_{t+1}$ and, using (1) and (2), we can solve for P_{t+1}. Finding the appropriate conditional expectation of P_{t+1} at t yields

$$(9)\qquad E_t(P_{t+1}|Z_t \geq Z_{tc}) = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1}.$$

Next note that if $Z_t = Z_{tc}$ from (7), Z_{tc} can be written in terms of a critical price P_{tc}

$$(10)\qquad Z_{tc} = \beta_0 - \alpha_0 + I_{t-1} + \beta_1 E_{t-1}(P_t) + \alpha_1 P_{tc},$$

where P_{tc} is a critical value for P_t. If $P_t < P_{tc}$, then $I_t > 0$, and if $P_t \geq P_{tc}$, then $I_t = 0$.

The Case of a Positive Carryout from Period t

If $Z_t < Z_{tc}$, then $I_t > 0$, and we have from (1)–(3) for period t

$$(11)\qquad I_t = \beta_0 - \alpha_0 + \beta_1 E_{t-1}(P_t) + \alpha_1 P_t + I_{t-1} - Z_t.$$

We view (11) as the supply for storage because it shows the amount from current production available for storage at alternative prices in period t. This relationship is similar to the excess supply function used by Samuelson for spatial and temporal models assuming certainty.[2]

In order to obtain the demand for storage, we write (1)–(3) for period $t + 1$, solve for I_t, and take the expectation of I_t conditional on $Z_t < Z_{tc}$. This yields

$$(12)\qquad I_t = \alpha_0 - \beta_0 - (\alpha_1 + \beta_1)E_t(P_{t+1}|Z_t < Z_{tc}).$$

Making the appropriate substitution from (4) we have

$$(13)\qquad I_t = \alpha_0 - \beta_0 - (\alpha_1 + \beta_1)P_t - (\alpha_1 + \beta_1)T.$$

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[1] As Holthausen and Feder, Just, and Schmitz have recently shown, the assumption that market agents base their decisions on expected prices, as if those prices were known with certainty, is much more plausible in the presence of futures markets than in their absence.

[2] The relationship given by (11) is not to be confused with Working's storage supply curve. Within our model, Working's curve may be construed as a locus of points generated by the intersection of the supply for storage as derived above and the demand for storage as shown in equation (13).

Equation (13) may be viewed as a demand for storage because it shows how much arbitragers will want to commit to storage at various current prices.

The supply and demand for storage, equations (11) and (13), respectively, can be used to solve for P_t and I_t as follows:

$$(14)\quad P_t = \frac{1}{2\alpha_1 + \beta_1}[2(\alpha_0 - \beta_0) - I_{t-1} - (\alpha_1 + \beta_1)T - \beta_1 E_{t-1}(P_t) + Z_t],$$

$$(15)\quad I_t = \frac{1}{2\alpha_1 + \beta_1}[- \beta_1(\alpha_0 - \beta_0) + (\alpha_1 + \beta_1)(\beta_1 E_{t-1}(P_t) + I_{t-1} - \alpha_1 T - Z_t)].$$

The expectation of P_t, which is now conditional on $Z_t < Z_{tc}$, yields

$$(16)\quad E_{t-1}(P_t|Z_t < Z_{tc}) = \frac{1}{2\alpha_1 + \beta_1}[2(\alpha_0 - \beta_0) - \beta_1 E_{t-1}(P_t) - I_{t-1} - (\alpha_1 + \beta_1)T + E_{t-1}(Z_t|Z_t < Z_{tc})].$$

Turning to period $t + 1$, we write (1)–(3) for period $t + 1$, substitute (15) into (3), thus getting rid of I_t. Finding the expectation of P_{t+1} conditional on $Z_t < Z_{tc}$ yields

$$(17)\quad E_t(P_{t+1}|Z_t < Z_{tc}) = \frac{1}{2\alpha_1 + \beta_1}[2(\alpha_0 - \beta_0) - \beta_1 E_{t-1}(P_t) - I_{t-1} + Z_t + \alpha_1 T].$$

Solving the System for Expected Values of the Endogenous Variables

We can now bring together the various strands of our argument to show how intertemporal solutions can be obtained. First, we use equations (6), (8), and (16) to obtain a relationship between Z_{tc} and $E_{t-1}(P_t)$ as follows:

$$(18)\quad E_{t-1}(P_t) = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} - \frac{1}{2\alpha_1 + p\beta_1}\left[\frac{p(\alpha_1 + \beta_1) + \alpha_1}{\alpha_1 + \beta_1} I_{t-1} + (1 - p)\alpha_1 T + (1 - p)E_{t-1}(Z_t|Z_t < Z_{tc})\right].$$

Derivation of this result takes advantage of

$$pE_{t-1}(Z_t|Z_t \geq Z_{tc}) + (1 - p)E_{t-1}(Z_t|Z_t < Z_{tc}) = 0.$$

Another relationship between Z_{tc} and $E_{t-1}(P_t)$ can be derived by finding the value of P_{tc} in (10). From (5) and (9) we know that P_{tc} cannot be less than $(P^* - T)$, where $P^* = (\alpha_0 - \beta_0)/(\alpha_1 + \beta_1)$. Next, let $P_{tc} > (P^* - T)$. Since, according to (7), P_t is a continuous upward sloping function of Z_t, Z_t could be lowered below Z_{tc} without inducing storage. This contradicts the definition of Z_{tc}.[3] Therefore it must follow that

$$(19)\quad P_{tc} = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} - T.$$

This is an entirely plausible result since, at P_{tc}, arbitragers can expect no profit from storage. However, if P_t falls below P_{tc} by an arbitrarily small amount, storage becomes immediately profitable. Substituting (19) into (10) yields the following additional relationship between Z_{tc} and $E_{t-1}(P_t)$:

$$(20)\quad E_{t-1}(P_t) = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} + \frac{1}{\beta_1}(Z_{tc} - I_{t-1} + \alpha_1 T).$$

Equations (18) and (20) form a two-equation system which can be solved for equilibrium values of Z_{tc} and $E_{t-1}(P_t)$. Once these solutions are obtained, values for $E_{t-1}(S_t)$, $E_{t-1}(D_t)$, $E_{t-1}(I_t)$, $E_{t-1}(P_{t+1})$, $E_{t-1}(S_{t+1})$, and $E_{t-1}(D_{t+1})$ can be readily determined. Importantly,

$$E_{t-1}(I_t) = (1 - p)E_{t-1}(I_t|Z_t < Z_{tc}), \text{ and}$$

$$E_{t-1}(P_{t+1}) = E_{t-1}[pE_t(P_{t+1}|Z_t \geq Z_{tc}) + (1 - p)E_t(P_{t+1}|Z_t < Z_{tc})].$$

The theory is determinate because knowledge of the system's parameters would allow expected values of all endogenous variables for periods t and $t + 1$ to be calculated. Variances of endogenous variables also could be estimated. Comparing the resulting estimates of expected values and variances (especially of price) with those associated with zero storage would provide valuable insights into the role of storage industries in market economies. Estimating expected producer and consumer surpluses compared to the zero storage case would also be instructive.

The reasons for our earlier assertion that the Helmberger-Weaver results are consistent with rational expectations only under restrictive assumptions may now be clarified. Helmberger and Weaver assume the existence of a critical value of I_{t-1}, say, I_{01} such that, for any $I_{t-1} \leq I_{01}$, the expectation of price in period t, formed at $t - 1$, depends on the assumption that $I_t = 0$ and $p = 1$. However, $I_{01} = (\alpha_1 + \beta_1)T$. For example, if $I_{t-1} = 0$, it can easily be shown that $E_{t-1}(P_t) = (\alpha_0 - \beta_0)/(\alpha_1 + \beta_1)$. If $I_{t-1} > I_{01}$, then $I_t > 0$ and $p = 0$. Obtaining the expression for $E_{t-1}(P_t)$ in this case necessitates introducing demand and supply for storage. With these simplifying assumptions, Helmberger-Weaver avoided serious complications, but their model is not wholly consistent with rational expectations. The question remains whether or not the resulting hypotheses have empirical validity.

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[3] Both equations (7) and (14) express P_t as linear functions of Z_t. At their point of intersection, $P_t = P_{tc}$ as derived in (19). To the right of Z_{tc}, equation (7) is relevant. To the left of Z_{tc}, equation (14) is relevant. Therefore, P_t is a kinked but continuous function of Z_t.

Comparative Statics of Storage under Uncertainty

To this point, linear demand and supply functions were assumed. The form of the density function for Z_t was left open. One way of proceeding is to postulate a specific form of the probability density function. The symmetric triangular distribution may be viewed as a rough approximation of several symmetric distributions and is particularly amenable to analysis. Therefore, we assume

$$(21) \quad f(Z_t)\begin{cases} = 0,\ Z_t < -d \\ = \dfrac{d-|Z_t|}{d^2},\ -d \le Z_t \le d \\ = 0,\ Z_t > d. \end{cases}$$

On this assumption, we can solve for p and $E_{t-1}(Z_t|Z_t < Z_{tc})$ as functions of Z_{tc}. Equations (18) and (20) can then be reduced to a single cubic equation in Z_{tc} as follows:

$$(22) \quad \frac{d}{6} + \frac{\alpha_1(2\alpha_1+\beta_1)}{\beta_1(\alpha_1+\beta_1)} I_{t-1} - \frac{\alpha_1}{\beta_1}(2\alpha_1+\beta_1)T - \left(\frac{\beta_1+4\alpha_1}{2\beta_1}\right) Z_{tc} + \frac{1}{2d} Z_{tc}^2 - \frac{1}{6d^2}|Z_{tc}^3| = 0.$$

Equation (22) is a reduced-form relationship. The value of Z_{tc} (and also of p, which is a function of Z_{tc}) depends on T and I_{t-1}. Using the rules of calculus for implicit and composite functions, it can be shown that for $-d < Z_{tc} < d$:

$$(23) \quad \begin{aligned} \frac{\partial Z_{tc}}{\partial T} &= -\frac{\alpha_1(2\alpha_1+\beta_1)}{2\alpha_1+p\beta_1} < 0 \\ \frac{\partial p}{\partial T} &= \left(-\frac{1}{d} + \frac{|Z_{tc}|}{d^2}\right)\frac{\partial Z_{tc}}{\partial T} > 0 \\ \frac{\partial Z_{tc}}{\partial I_{t-1}} &= \frac{\alpha_1(2\alpha_1+\beta_1)}{(\alpha_1+\beta_1)(2\alpha_1+p\beta_1)} > 0 \\ \frac{\partial p}{\partial I_{t-1}} &= \left(-\frac{1}{d} + \frac{|Z_{tc}|}{d^2}\right)\frac{\partial Z_{tc}}{\partial I_{t-1}} < 0. \end{aligned}$$

As storage costs increase, storage of production from period t becomes less likely; p increases and Z_{tc} falls. As the carryin, I_{t-1}, increases, it becomes more likely that I_t will be nonzero; p declines, and Z_{tc} increases. Using the equations in (23), partial derivatives of the expectations of all endogenous variables with respect to T and I_{t-1} can be obtained. These results are given in table 1.

Most of the hypotheses summarized in table 1 are intuitively appealing. However, we are unaware that they have been given a rigorous derivation in the previous literature. For illustration, an increase in I_{t-1} causes expected prices in both t and $t+1$ to decline. Expected consumption increases in both periods but expected production falls.

A competitive market abhors a zero carryin. For example, consider the case where storage is prohibitively expensive—T is sufficiently large so that $Z_{tc} \le -d$. If storage cost then falls, Z_{tc} will eventually rise above $-d$, and storage will emerge. One effect will be a rise in the expected price in period t, stimulating expected production. At the same time, expected consumption will fall. The effect, clearly,

Table 1. Partial Derivatives of Expected Values of Endogenous Variables

Expected Endogenous Variables	Partial Derivatives with Respect to:	
	Storage Cost (T)	Carryin (I_{t-1})
$E_{t-1}(P_t)$	$\frac{1}{\beta_1}\left(\frac{\partial Z_{tc}}{\partial T} + \alpha_1\right) < 0$	$\frac{1}{\beta_1}\left(\frac{\partial Z_{tc}}{\partial I_{t-1}} - 1\right) < 0$
$E_{t-1}(S_t)$	$\beta_1 \frac{\partial E_{t-1}(P_t)}{\partial T} < 0$	$B_1 \frac{\partial E_{t-1}(P_t)}{\partial I_{t-1}} < 0$
$E_{t-1}(D_t)$	$-\alpha_1 \frac{\partial E_{t-1}(P_t)}{\partial T} > 0$	$-\alpha_1 \frac{\partial E_{t-1}(P_t)}{\partial I_{t-1}} > 0$
$E_{t-1}(I_t)$	$\frac{(1-p)(\alpha_1+\beta_1)}{2\alpha_1+\beta_1} \frac{\partial Z_{tc}}{\partial T} < 0$	$\frac{(1-p)(\alpha_1+\beta_1)}{2\alpha_1+\beta_1} \frac{\partial Z_{tc}}{\partial I_{t-1}} > 0$
$E_{t-1}(P_{t+1})$	$-\frac{(1-p)}{2\alpha_1+\beta_1} \frac{\partial Z_{tc}}{\partial T} > 0$	$-\frac{(1-p)}{2\alpha_1+\beta_1} \frac{\partial Z_{tc}}{\partial I_{t-1}} < 0$
$E_{t-1}(S_{t+1})$	$\beta_1 \frac{\partial E_{t-1}(P_{t+1})}{\partial T} > 0$	$\beta_1 \frac{\partial E_{t-1}(P_{t+1})}{\partial I_{t-1}} < 0$
$E_{t-1}(D_{t+1})$	$-\alpha_1 \frac{\partial E_{t-1}(P_{t+1})}{\partial T} < 0$	$-\alpha_1 \frac{\partial E_{t-1}(P_{t+1})}{\partial I_{t-1}} > 0$

is to establish an inventory for protection against possible scarcity in the next period.

Implications

These developments suggest both further theoretical analysis and empirical research. Risk-averse behavior, the presence of futures markets, the effects of exogenous shocks on price variance and on expected consumer and producer surplus, and generalizations to include multiple products and the horizons beyond two periods are topics meriting further attention.

Importantly, experimentation with a numerical example suggests that given the values for all parameters, including those describing the probability density function, extension of the horizon beyond period $t + 1$ is quite feasible. The algorithm draws upon inventory theory as used in the work of Gustafson. Where the terminal period is $t + 2$, for example, start with the last two periods, recognizing that the expected values of the endogenous variables for these periods can all be expressed as functions of the carryin from period t. Selecting a sample of values for I_t allows estimating the relationship between $E_t(P_{t+1})$ and I_t statistically and then using this relationship in lieu of (12) in deriving the demand for storage in period t. The supply for storage is derived as in the development of equation (11).

These theoretical results may help to answer empirically such questions as: Does private storage within a market system characterized by uncertainty tend to stabilize or destabilize price and output over time? Is economic efficiency increased, decreased, or optimized? What happens to producers' and consumers' welfare? What are the effects of government storage programs which affect both price expectations and private storage decisions?

Where good measures of expected prices can be found, such as futures prices, the supply equation could be estimated directly using ordinary least squares. The demand parameters could be estimated using two-stage least squares. Exogenous variables used in estimation could be impounded in constants α_0 and β_0. Analysis of the error terms in the supply and demand equations might allow an approximation of the probability density function for Z_t. Such quantified models that pass validation tests might then be used to compare the full economic effects of competitive storage against alternative government storage policies.[4] Only by applying this or a similar research procedure to many commodities will economists be able to provide support for generalizations about the temporal effects of private and/or public storage decisions.

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[4] The research procedure suggested here differs from that suggested by Peck. She writes (p. 127), "The relationship in Chart 1 reflects the complex interaction of consumption demand (export and domestic) and storage demand. In a complete model, these demand curves should be estimated simultaneously." According to the theory presented here, if reliable estimates of the parameters of supply for production and demand for consumption are available, then the demand and supply for storage may be deduced; they need not be estimated. It should be emphasized that our results depend critically on equations (4) and (5).

Agricultural Price Supports and Cost of Production

John R. Groenewegen and Kenneth C. Clayton

The purpose of this note is to discuss the economic rationale for farm price supports and to illustrate how production costs can be used to establish them. In so doing, a classification of production costs is presented to provide the basis for establishing price supports in an economically justifiable manner. Thus, we challenge Pasour's view that "the use of cost data as a basis for agricultural price supports is 'economically indefensible' " (p. 244).

Price supports can be based on production costs, but only if the costs of factors that are fixed in the short run are not directly included in the support calculations. These factors have economic costs and are captured in a residual. This view merely recognizes that economic rent is a price-determined, not a price-determining, cost.

Rationale for Price Supports

Parity was the basis for price support until fairly recently for most commodities. The concept underlying parity was to maintain purchasing power in the farm sector commensurate with that in the 1910–14 period. While the concept was generally accepted, its measurement tended to be more problematic. Parity price calculations did not account for powerful technological and structural shifts that occurred over time. As a result, parity prices and market prices often tended to diverge rather widely. For these reasons, the basis for price supports was changed from parity to cost of production in the 1970s.

The need for price supports stems from the market instabilities that agriculture faces and from unmatched changes in expenditures relative to receipts. In the case of grains, for example, output price instability arises in today's economic environment because of capricious weather patterns, large but irregular market activity by some importers, exchange rate movements, and insulationist trade policies. At the same time, expenditures on inputs escalate because of general price inflation and can command a larger portion of receipts.

The rationale for price support prices should be to allow immediate, or cash, expenditures to be met. In so doing, assurance is provided that the productive capacity in agriculture is maintained without traumatic adjustment. Price supports should not provide owners of fixed agricultural resources the opportunity costs of these resources. The latter should come from the market. This point was discussed at a U.S. Senate hearing in 1979, where a U.S. Department of Agriculture (USDA) official noted that the objective for price supports was to provide "necessary cash for current expenses" and a "safety net protecting producers from the consequences of disaster level prices when supplies are in excess of market requirements." Although one may quibble that a short-run production expense for one firm may not be a short-run expense for another, the point to be made is that supports are not designed to maintain the expected opportunity costs of fixed resources. Instead, the objective is to provide a cash flow to farmers when market prices deviate substantially and temporarily below trend.

Price supports should not attract additional resources into the sector. This is the role of market prices. Rather, supports should prevent the unnecessary exit of resources when market prices are temporarily depressed. Price supports should not preclude resource adjustment. They should assure that resources are not forced to adjust unnecessarily.

Adjustment of Price Supports

Establishing the initial level of a price support tends to be much easier than adjusting it. In today's economic setting, the level of a price support should be established below trend market prices. If the rationale underlying the support is not adequately articulated and reflected in the adjustment scheme, then the adjusted supports over time may deviate substantially from the intended goal. This was the problem with the parity index since it did not adequately reflect economic well-being over time. The adjustment formula for target prices in the Food and Agricultural Act of 1977 also failed to adjust supports adequately because the adjustments were based on lagged cost changes which did not reflect current conditions. Including lagged actual yields to reflect productivity proved to be inadequate, too. Support prices also may exceed trend market prices with an inappropriate adjustment mechanism.

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Hence, the rationale for price supports must be quantifiable, and the adjustment mechanism should reflect economic considerations and not just accounting costs.

A Production Cost Hierarchy

Confusion often arises in discussions of production costs and price supports. At times, all costs are treated the same, although there usually is some recognition of immediacy (e.g., cash versus noncash costs). Sometimes costs are computed in an economic framework. However, these two categories are rarely brought together. In this section, a cost classification is offered which does bring these categories together in a price support context.

Production costs may be classified according to two schemes (*a*) purchased factor costs and economic rent and (*b*) cash and noncash costs. At the first level in this classification scheme, total costs are segmented into purchased factor costs and economic rents. Purchased factor costs are associated with variable inputs (e.g., fertilizer) as well as nonland physical capital (e.g., buildings and machinery). Economic rent is the residual return to fixed factors, namely land and operator-management services. The residual is equal to the difference between total receipts and purchased factor costs. Total costs, by definition, equal total receipts since economic rent is price-determined.

At the second level of classification, cash costs are defined as immediate payments to fixed and variable factors. These include variable expenses (such as fertilizer, fuel, repairs, and hired labor), some overhead expenditures, land rents, land taxes, and some portion of the basic living expenses for the family unit. Noncash costs are incurred in the production period, but their payment can be postponed to subsequent periods (e.g., depreciation on capital equipment). Noncash costs also include current returns to fixed resources (land and operator-management services) above cash obligations. The addition of cash and noncash costs, by definition, equals total costs which, in turn, equal total receipts. (This analysis does not consider noncash or equity returns that occur in agriculture. Hence, cash expenditures can exceed current receipts when a producer invests heavily into an appreciating asset like land.)

Within this hierarchy, it is evident that economic rent has a cash as well as noncash component. The cash component of economic rent includes land rent, land taxes, land mortgage payments, and basic living costs that are apportioned to the production activity in question. The remaining portion of economic rent which does not have an immediate cash obligation is the noncash component. Similarly, some purchased factor costs, such as variable costs, are strictly cash expenditure items; whereas machinery costs, for example, have a cash expenditure (interest and principle payments) and a noncash component (depreciation allowances). These cost concepts are illustrated in table 1.

Management has little control of cash expenditures during the production period. Besides liquidating, management has flexibility only in utilizing fewer variable inputs and thereby reducing associated cash expenditures. The cash obligations on the remaining purchased factors are fixed cash expenses as are cash obligations on specialized resources during the production period. The factors or inputs associated with these fixed cash expenses are responsible for the theoretical measurement problems of cost and price supports.

Noncash costs directly affect the discretionary income available to management during the production period. Discretionary income is the difference between output returns and fixed plus variable cash expenditures. It can be used by management for savings, increased family consumption, firm growth, and replacement of depreciable items. In the short run, the production unit must maintain a positive discretionary income. If not, cash obligations could exceed cash receipts, and the farm could be forced to liquidate (unless the operator is able to borrow against the appreciated value of capital assets).

In the longer run receipts must cover more than short-run fixed and variable cash expenses. The full cost of depreciable items must be covered if the production unit is to remain economically viable. Receipts must at least cover all purchased factor costs and the cash component of economic rent, where the latter are referred to as assigned costs, table 1. The difference between assigned costs and total receipts is unassigned economic rent. Unassigned economic rent can be utilized by management just as short-run discretionary income.

Short-run solvency of the farm requires that discretionary income not be negative. Viability of the farm in the long run requires that cash receipts at least cover costs assigned to the production unit.

Price Supports Adjusted by Costs

Our rationale for price supports is consistent with a support level that provides for cash expenditures contracted by management during the production period. For many producers, a significant portion of economic rent has a cash obligation which makes these producers extremely vulnerable to downward swings in economic rent. The latter results from declining receipts or increasing input expenditures. Consequently, covering cash production costs via supports requires that some portion of economic rent be covered.

Variable cash costs can be supported directly since they are easily measured and not directly associated with resources unique to agriculture. However, cash expenditures for resources fixed in the production period cannot be supported directly because the supported expenses associated with

Table 1. Agricultural Production Cost Hierarchy and Discretionary Income

Classification of Production Costs[a]			Examples of Cash and Noncash Costs	Classification of Costs by Management in the Production Period	Contributes to Discretionary Income	Classification of Cost by Management over a Number of Production Periods
By economic costs	By Factors	By Cash and Noncash Costs				
Purchased factor costs	Variable	Cash	Fertilizer expenditure	Variable cash expense	No	Assigned costs
	Machinery	Cash	Interest paid	Fixed cash expense	No	Assigned costs
		Noncash	Capital consumption	Unassigned purchased factor cost	Yes	Assigned costs
	Overhead	Cash	Telephone	Fixed cash expense	No	Assigned costs
Economic rent	Land	Cash	Cash rent	Fixed cash expense	No	Assigned costs
		Noncash	Return to land	Unassigned economic rent	Yes	Unassigned economic rent
	Operator-management	Cash	Required family consumption expenditure	Fixed cash expense	No	Assigned costs
		Noncash	Return to operator-management	Unassigned economic rent	Yes	Unassigned economic rent

[a] Where total costs equal total receipts.

economic rent could very well exceed the rent value that would occur without supports. If this occurs, supported economic rent effectively determines price, and price supports become capitalized into agricultural assets—usually land. Economic rent then becomes price-determining and not price-determined.

Fixed cash expenses can vary substantially across producers and are almost impossible to measure as a national average. Cash expenditures on land vary according to tenure status and acquisition date. In addition, family living expenses apportioned to a specific enterprise, e.g., wheat, depend on the size and type of farm and nonfarm enterprises. Furthermore, cash expenses for capital items depend on the purchase date and outstanding capital debt. These fixed cash expenses, table 1, are mostly for resources that are fixed in the production period. Such items are virtually unique to each unit. Just as difficult to measure are opportunity costs of these resources which are unique to the owners (Pasour).

Fixed cash expenditures are largely determined by the level of discretionary income in past production periods and/or the level of economic rent. That is, past output price is an important determinant of current fixed cash expenditures. For example, land values increase when short-run economic rent increases and buyers expect similar conditions to continue. In turn, higher land values increase the cash component of economic rent for producers who purchase additional land and for renters. This relationship between expenditures and past discretionary income is illustrated by the relationship between agricultural asset values and returns to agriculture (Melichar) in combination with the sharp increase in voluntary farm transfers that occurred during the early 1970s when agricultural returns increased substantially (USDA 1980, tables 597 and 608).

These fixed cash expenditures can be supported in relation to the income available to offset them—receipts minus variable cash expenditures. This is discretionary income available for fixed cash expenditures. Price supports can simply be set equal to projected variable costs plus some percentage of a moving average of receipts minus variable cash expenses. Algebraically, this price support scheme can be expressed as

$$(1) \quad PS_t = VC_t^P + [K \sum_{i=t-4}^{t-1} (P_i - VC_i) \times .25],$$

where PS_t is price support for crop year t; VC_t^P is projected variable costs for crop year t based on trend yield; P_i, season average price in crop year i (t = 4 for illustrative purposes only); VC_i, actual variable expenditures in crop year i; and K, the proportion of past discretionary income available for fixed cash expenditures, a constant.[1]

Past receipts and variable costs preserve the market relationship between output price and economic rent. The adjustment procedure reflected in the second term of equation (1) assures that supported cash expenditures for specialized resources will not exceed the trend rent that would occur in the absence of price supports. Because this term is a moving average, the support scheme has an implied sunset clause which temporarily protects higher fixed cash expenditures resulting from higher past prices which induce replacement investment and farm expansion. In addition, when income available for fixed cash expenditures declines, the support scheme does not allow agricultural resources to be valued higher than without the support. This adjustment procedure virtually precludes capitalization of price supports.

Table 2 illustrates the use of these concepts as a basis for price support. Actual and projected variable costs for corn and wheat are shown in the first two columns of table 2. Season average prices are in the third column.[2] The difference between the first and third column is discretionary income available for fixed cash expenditures and is shown in the fourth column. The moving four-year average of discretionary income available for fixed cash expenditures is shown in the fifth column of table 2.

Column 6 illustrates the computed price support. It is the projected variable costs for the year plus 50% of the previous four-year average of discretionary income available for fixed cash expenses. Fifty percent was employed in this illustration because, at the national level, USDA farm income statistics indicate that 42% to 50% of discretionary income available for fixed cash expenditures was a cash obligation in the 1977 to 1980 calendar years (USDA 1981, table 3).[3]

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[1] The Western Grain Stabilization program in western Canada is similar to the concept embedded in equation (1). The program assures participating producers that average net cash flow (gross cash receipts minus cash operating costs) does not fall below the previous five-year average net cash flow—i.e., K = 100. Additionally, the program is based on cash flow for a region, and it is not crop-specific.

[2] Variable costs and season average prices in table 2 are based on USDA data.

[3] Using table 3 in the USDA publication, discretionary income available for fixed cash expenditures is defined as cash sources minus cash uses on intermediate product expenses.

Table 2. Price Supports for Corn and Wheat Based on Variable Cash Expense Plus a Moving Average of Discretionary Income above Variable Costs

Crop Year	Actual Variable Costs (1)	Projected Variable Costs (2)	Season Average Price (3)	Discretionary Income Available for Fixed Cash Expenditures[a] (4)	Average Discretionary Income Available for Fixed Cash Expenditures for the Preceding Four Years (5)	Price Supports: Projected Variable Cost Plus K% of Average Discretionary Income Available for Fixed Cash Expenditures[b]: K = 50% (6)	Price Supports: Projected Variable Cost Plus K% of Average Discretionary Income Available for Fixed Cash Expenditures[b]: K = 65% (7)	Actual Loan Rate (8)
				($/bushel)				
Corn								
1974	1.12	—	3.02	1.90	—			
1975	1.06	—	2.54	1.48	—			
1976	1.07	—	2.15	1.08	—			
1977	1.09	—	2.02	.93	—			
1978	.98	1.08	2.25	1.27	1.35	1.76	1.96	2.00
1979	1.03	1.12	2.52	1.49	1.19	1.72	1.89	2.10
1980	1.51	1.42	3.20	1.69	1.19	2.02	2.19	2.25
1981	1.57	1.57	—	—	1.14	2.24	2.44	2.40
Wheat								
1974	1.28	—	4.09	2.81	—			
1975	1.39	—	3.56	2.17	—			
1976	1.46	—	2.73	1.27	—			
1977	1.34	—	2.33	.99	—			
1978	1.24	1.38	2.98	1.74	1.81	2.29	2.56	2.50
1979	1.39	1.39	3.82	2.43	1.54	2.16	2.39	2.75
1980	1.86	1.81	4.00	2.14	1.61	2.62	2.86	3.00
1981	2.13	2.13	—	—	1.82	3.04	3.31	3.20

[a] Season average price minus variable costs.

[b] See the formula in equation (1).

The computed price supports with $K = 50\%$ are lower than the actual price supports for the past four years, columns 6 and 8 of table 2. The 1978 corn and wheat loan rates of \$2.00 and \$2.50 per bushel, respectively, were established by the Food and Agricultural Act of 1977. Using the proposed support adjustment mechanism, the actual loan values for the remaining years suggest K's equal to 68% for corn and 62% for wheat.

Support prices for corn and wheat which cover 65% of past discretionary income available for fixed cash expenditures are presented in column 7 of table 2. These prices for 1978–81 provide support comparable to that established by legislation. Support prices using the adjustment procedure of equation (1) are close to actual loan rates, except for 1978. In that year, the discretionary income available for expenditures on fixed factors decreased from the 1977 level.

The mechanism being proposed ensures that, for the average producer, cash expenses in the production period are covered by supports. In fact, with $K = 65\%$, more than current cash obligations are supported according to the aggregate income statistics. In this situation, additional resources may be attracted into agriculture. However, the support scheme proposed does not ensure that the cash expenditures on newly acquired resources are fully covered.

Given the cash flow rationale that we attribute to price support policy, production costs can be used to establish price supports in an economically defensible manner. To do so requires making a distinction between purchased factor costs and economic rent. It requires recognition of the residual nature of economic rent, and that there are cash expenditures associated with economic rent. The irreconcilable measurement problems of fixed resource costs and depreciable capital items is avoided, and it does not result in capitalization of price supports. The illustrated support mechanism assures the average existing producer coverage of at least fixed and variable cash expenditures and is designed to smooth the process of resource adjustment.

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Rail/Truck Competition for Grain Traffic in Minnesota: Implications for Rate Making

Gregory H. Michaels, Richard A. Levins, and Jerry E. Fruin

The simplest model of railroad rate making is that trucks are more cost-efficient for short hauls and railroads for long hauls. Unfortunately for the railroads' market share, the "long" haul gets longer with each new round of rate increases. This has been particularly true for grain traffic in Minnesota.

In this paper, an analysis of rail/truck competition for Minnesota's grain traffic is presented. It suggests a reconsideration of the long- and short-haul categories normally assumed for railroads and trucks since railroads are being granted more rate-making discretion. We argue that the annual rail volume generated by various areas is at least as important as the route length within those areas in determining transportation costs for bulk commodities. Both distance and volume must be considered in rate implementation to avoid distortions in mode selection.

Trends in Grain Rates

The first task is to examine single-car rail and truck rates in effect for Minnesota grain and soybeans during 1970–79. In this period, both railroad and truck rates for grain and soybeans were regulated. (Although motor carriage of grain and soybeans is exempt from interstate rate regulation, minimum rates for intrastate movements have been regulated by the Minnesota Public Service Commission since 1970.)

A county-by-county comparison of truck and single-car railroad grain rates for 1970–79 was made using railroad and truck rates for the years 1970, 1973, 1975, 1977, and 1979. Rates were collected for soybeans and corn (both are the same) from the seat of each of sixty-nine grain-producing counties to Minneapolis. The point of using this simplified transportation pattern was to highlight rate structure changes. Minneapolis is a major, but not the only, destination for intrastate grain shipments.

In 1970, the first year in which both railroads and trucks were regulated in Minnesota, the two were strongly competitive for grain traffic. Thirty of the sixty-nine counties had single-car rail rates to Minneapolis lower than corresponding truck rates, and eighteen counties had less expensive truck rates. Truck and rail rates to Minneapolis from twenty-one counties were identical.

In 1973, the year of the Arab oil embargo and the first round of recent fuel price increases, railroads continued their domination of short-haul grain rates. Truck rates rose faster than rail rates during 1970–73. In 1973 only eight of the sixty-nine counties showed a definite advantage for trucks. Three counties had equivalent rail and truck rates, and the remaining fifty-eight counties showed a definite advantage for rail.

Only two years later, the situation was completely reversed. No county had a definite rail rate advantage, sixty-six would have been better off using trucks, and three counties had equal rail and truck rates. Truck rates increased during 1973–75, but railroad rate increases during those years were much sharper. By 1977, no county showed a single-car rail rate to Minneapolis lower than the competing truck rate. This remained unchanged in 1979.

The rail and truck rates were regressed against distance using ordinary least squares to obtain an estimate of the rate as a linear function of miles. The results, shown in table 1, provide insight into the decline of single car haulage in the study area. The ratio of the slope coefficients (which presumably reflects relative per mile variable costs) between the two modes remained remarkably constant throughout the study period, even though both coefficients approximately doubled. The change in intercept (which should reflect that traffic's contribution to fixed cost) shows a much different picture, especially for the 1973–79 period of rapid rail decline. The truck intercept declined slightly, while the rail intercept nearly tripled.

Spatial Distribution of Grain Production

As the intercept of single-car rail rates increases relative to truck rates, trucks capture business over longer and longer hauls. However, the total business lost by the railroads depends upon the spatial distribution of grain production. To understand better the implications of the change in rate structures presented in the previous section, the spatial distribution of grain production in the study area, and consequent transportation volume potential, was examined.

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Table 1. Single-Car Rail and Truck Grain Rate Functions in Minnesota

Year	Rate Equation	R^2
1970	$T = 4.30 + .095\,M$[a]	.997
	(.0009)	
	$R = 5.35 + .088\,M$	.899
	(.0036)	
1973	$T = 9.30 + .095\,M$	.997
	(.0009)	
	$R = 6.37 + .106\,M$	.895
	(.0044)	
1975	$T = 8.96 + .12\,M$	.997
	(.0011)	
	$R = 13.16 + .125\,M$	.813
	(.0073)	
1977	$T = 8.22 + .15\,M$	.997
	(.0015)	
	$R = 14.31 + .137\,M$	.818
	(.0079)	
1979	$T = 8.82 + .18\,M$	.996
	(.0021)	
	$R = 17.33 + .161\,M$	.807
	(.0096)	

[a] M is highway miles from county seat to Minneapolis, T is truck rate (¢/cwt.), and R is rail rate (¢/cwt.); standard errors are in parentheses; equations were estimated for respective years using data for 69 Minnesota counties. Data sources are listed in Michaels, Fruin, and Levins.

The sum of the 1970–79 average soybean production and one-half of the 1970–79 average corn production was calculated for the counties in the study area. Only one-half of the corn crop was included to reflect the relatively large proportion of Minnesota's corn production that is used on-farm. These production figures are shown in table 2. Since a ton produced a short distance from markets translates into fewer ton miles than one produced farther away, the production of each county was multiplied by its distance from Minneapolis to obtain a ton-mile traffic volume potential indicator. Those figures, which are also shown in table 2, are the ones of most interest here.

Production within a range of 0–60 miles from Minneapolis is relatively low. Since the distances are short, the volume potential of counties in close proximities to Minneapolis is also low. However, both production and ton-miles are at their maximum for counties in the 61–120 mile range rather than for counties at greatest distance from Minneapolis. The volume potential of counties in the 121–180 mile range is slightly less than the next closest range, and the production and volume potential of the most distant counties is quite low. Consequently, the result of the rising intercept in rail rate functions has been to drive rail transportation out of the market in areas with large volume potential. The economic and institutional forces which combined to yield this result are examined in the following theoretical discussion.

Table 2. Distribution of Corn and Soybean Production in Forty-Six Selected Minnesota Counties, 1970–79 Averages

Miles from Minneapolis	Production	Transportation Volume
	(1,000 tons)	(1,000 ton-miles)
0–60	978	39,768
61–120	7,029	693,797
121–180	3,536	538,818
181–240	378	75,527

Theoretical Considerations

A traditional model of rail/truck competition for traffic in a given commodity (figure 1) can be used to further analyze the decline of railroad grain haulage in Minnesota. Both truck and rail rates are expressed as functions of distance hauled in this familiar graphic representation. It is assumed that variable truck costs are higher than those for railroads; hence, the truck rate line has a steeper slope. Railroads, on the other hand, are assumed to have a higher fixed cost (Martin and Dahl). Given these assumptions, the two rate lines which are presumed to reflect these cost differences cross at some distance d_1, short of which trucks have a rate advantage and beyond which railroads have the advantage.

It is important to note that fixed costs relate to a time period and that the truck and rail intercepts in figure 1 express fixed costs on a per unit, not a total dollar, basis. There is an underlying assumption in the model that some particular number of units is

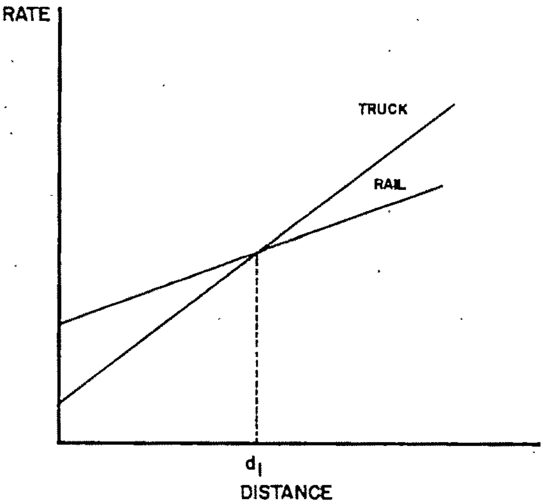

Figure I. Traditional model of rail/truck competition.

Figure 1. Traditional model of rail/truck competition

hauled by each mode during some time period or else the intercept could not be determined, i.e., fixed costs per unit are necessarily based on estimates of the volume that will be moved. Before pursuing this notion further, a brief digression on fixed costs and industrial structure for the two modes is in order.

The substantial difference in fixed costs incurred by trucks and railroads consists largely of differences in way and terminal costs. Railroads own and operate their roadbed and terminals, while grain-trucking firms operate on publicly owned and maintained roads and do not require terminals. Through the mechanism of fuel taxes, most of the fixed costs of highway construction and maintenance are converted to a variable cost for the individual trucking firm. Larger administrative burdens also contribute to larger railroad fixed costs.

Regarding industrial structure, trucking activities within a given market area are more atomistic than railroad activities serving the same area. In the face of a change in demand for its services, the trucking industry can, in time, adjust its size. Individual firms may enter or leave in the face of changing aggregate demand for trucking, thereby keeping the industry's total rolling stock at some appropriate size for efficiently handling the current demand for its services. Entry and exit also serve to adjust the industry's aggregate charge for highway use since highway user fees are assessed through licenses and fuel taxes per truck. Thus, there are mechanisms at work which tend to tailor fixed costs to aggregate demand levels. The "fixed cost per unit hauled," i.e., the truck intercept in figure 1, can therefore be expected to remain fairly stable with respect to the demand for trucking services.

The situation for railroads is quite different. Given time, they can, like the trucking industry, adjust their rolling stock to suit changing demands. But the public does not own and operate trackage and charge the railroad a fee based on current usage of that track. Rather, a railroad owns and operates a roadbed of given size, with little flexibility for adjusting way costs as market shares change. Substantial changes in roadbed cost reductions can come about only through the politically arduous task of abandonment proceedings. The railroads' total fixed cost is, therefore, less sensitive to changes in volume than is that of the trucking industry. A railroad will have a relatively low fixed cost per unit over a route of some given distance if annual volume over that route is high and a relatively high fixed cost per unit if volume is low.

In figure 2 the assumption is made that rail rate lines R_1, R_2, and R_3 reflect cost lines corresponding to three annual volume levels, and that railroads are initially operating at rate R_1 with no truck competition. If trucks enter the market with rate line T, point d_1 becomes the distance at which the competitive advantage changes between the two modes. The effect of this from the railroads' point of view is that the volume originating at distances less than d_1 is lost to truck competition. Since the railroad cannot adjust its fixed costs and there are fewer units being shipped by rail, fixed cost per unit increases. A higher cost line results.

The railroads now request a rate increase to R_2, which supposedly reflects the new cost structure. But adopting R_2 causes the competitive break-even distance to move out to d_2, and the railroads are forced to seek another rate increase to compensate for the additional lost volume. The resulting process of railroad retrenchment plausibly could continue indefinitely; in the limit, truck transportation would entirely displace rail. In fact, this process is constrained by truck rate increases, rail line abandonment, and the actual volume lost with each round of rail rate increases. This latter factor is dependent on the spatial distribution of potential traffic in the route service area.

The argument presented here is consistent with the empirical findings of the Minnesota case study. As the break-even mileage crept outward, the rich grain territory at relatively close distances to Minneapolis shifted from railroads to trucks. The business for railroads was inadequate to cover fixed costs without large increases in the intercept of the rail rate structure. This, in turn, made trucks competitive at even greater distances. More rail business was lost, and the cycle continued with devastating effectiveness. Consequently, the ton-miles that would have been hauled by trucks if shippers only considered relative cost increased by a factor of six during 1973–79.

Implications for Rate Making

The problems resulting from reduced fixed-cost coverage for railroads in the move from R_1 to R_2 in figure 2 could have been at least partially avoided if

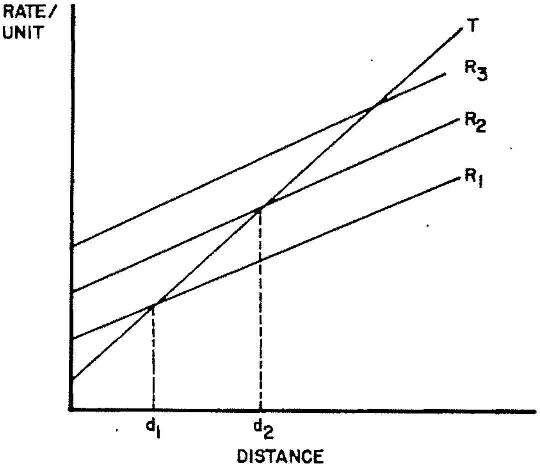

Figure 2. Illustration of rail/truck competition

the railroads had raised rates to only those customers situated beyond distance d_1. The failure of railroads to discriminate rationally in rates between short- and long-hauls has been due to several things.

First of all, some legal constraints imposed on rail transportation by the Interstate Commerce Commission have conditioned the rate structure. While ICC regulations may permit differential pricing across commodities that is not deemed "unjustly discriminatory," historically Section 4 of the Interstate Commerce Act explicitly prohibited discrimination by railroads between long- and short-haul rates for the same commodity, unless express permission was granted by the ICC (Harper). Second, because of the inherent controversies generated among users in setting multiple rates, railroads have found it administratively easier to petition for consistent rates and *ex parte* rate increases. Consequently, rail rates are petitioned for and set to conform to the rate-distance model shown in figure 1 even though railroads set different rates for different commodities based on value of service and other considerations.

The rate model of figure 1 worked well enough for the circumstances under which it was devised, i.e., a lack of effective truck competition. Without trucks, the railroads faced an inelastic demand for their services in most cases, and the "rate gouging" which led to the formation of the Interstate Commerce Commission (ICC) was a genuine threat. When railroads were judged by the ICC to be in need of increased revenues to offset increased costs, the usual flat percentage increases applied across the board served their purpose in an uncomplicated way.

The rise of the trucking industry has changed the workings of the cost-based rate-making philosophy which underlies both the model of figure 1 and the encouragement of across-the-board rate increases. For railroads, it is no longer only a matter of costs determining rates; it is also a matter of rates determining costs through volume effects. As is shown in figure 2 and in the Minnesota case study, this "simultaneity" between railroad costs and rates can have significant effects on rail/truck competition if it is not explicitly considered in rate making.

Concluding Remarks

In October 1980, President Carter signed the Staggers Rail Act into law. While railroad groups argue that the Staggers Act amounts to "reregulation," the purpose of the legislation was to deregulate gradually the rate-making process in the rail industry. Several features of the Staggers Act are particularly noteworthy in the context of this paper. The current law provides that the antidiscrimination clause of the Interstate Commerce Act does not apply to contracts, surcharges or cancellation of routes, separate routes for distinct services, or rail rates applicable to different routes. The minimum rate provisions of the Staggers Act also allow railroads to reduce rates to meet motor and barge competition, as long as rates are equal to or greater than variable cost. These provisions make it easier for railroads to discriminate rationally in rate setting between the short- and the long-haul. To the extent that railroads take advantage of these provisions, intrastate rail transportation activity in high volume, short-haul markets should increase.

There are, of course, many other factors, such as quality of service and grain storage capacity utilization, which affect mode selection. The competitive positions of railroads and trucks will be further influenced by recent changed in tax laws, the outcome of discussions for restructuring barge and truck rates, decisions on costs and capacity of river transportation, and consequent investment in and location of multiple-car rail facilities. Nonetheless, in areas where the density of grain production is sufficiently high, railroads may be expected to use their new rate-making freedom to make some inroads against trucks. In these cases, economies of size in transportation will add impetus toward greater concentration in commodity assembly and transshipment. For regions where production is more sparse, trucks may still dominate over relatively long hauls.

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The Effect of Electricity Prices, Lift, and Distance on Irrigation Development in Idaho

Joel R. Hamilton, Gary S. Barranco, and David J. Walker

Irrigated agriculture in southern Idaho dates from the 1840s when pioneers first tapped the Snake River and its tributaries. Reclamation of land bordering the rivers spread to become the base of a food production and processing industry which today is the backbone of the southern Idaho economy. About 3.8 million acres of Idaho land are now irrigated, and nearly 8 million more have soils and slopes amenable to irrigation (Idaho Water Resource Board). There is growing interest in the potential for, and consequences of, continued irrigation development in the Pacific Northwest. The Northwest Agricultural Development Project recently completed a major study of these issues. The U.S. Bureau of Land Management (BLM) has published an environmental statement concerning a proposal to allow development of a large tract of public land in southwest Idaho. While generally favorable crop prices have stimulated farmer and investor interest, sharp increases in electric rates have caused concern among both existing and potential irrigators.

The better and more easily developed land naturally was irrigated first. Development of the remaining land, much of it high benchland above the Snake River, would require high lift pumps and long canals or pipelines to carry the water. Because of farm size limits in existing laws governing irrigation development, projects usually consist of a number of separate farm units with a common pumping plant to lift water from the river. One new project has over 20,000 acres and three pumping plants totalling 55,000 horsepower to lift the river water 600 feet.

Recent literature on irrigation development focuses on social returns from irrigation projects (Young; Martin; Stoevener and Kraynick; and Long, Nelson, Potratz). If net social benefits can be realized, committing public resources to irrigation projects is justified. The BLM "Organic Act" charges that agency with weighing the public interest in disposing of public land for private use. Since irrigation development requires the use of private resources, the factors which affect private profitability will be important determinants of the extent, timing, and location of new irrigation. In addition, private returns are an important component of the social benefits from an irrigation project.

Procedures now being used by the BLM to assess development applications focus almost exclusively on private economic feasibility, ignoring wider social costs and benefits. It is likely that the BLM's private economic feasibility criterion overstates the net social benefits of development because of the high cost of using thermal power plants to generate the electricity for running the pumps and to replace hydropower lost when water is diverted for irrigation. A paper by Hamilton and Whittlesey outlines these energy issues which are important in the Pacific Northwest.

Conversely, the private economic feasibility criterion (as currently interpreted by BLM) understates the feasibility of private development because it ignores a range of financial development incentives including investment tax credit; tax treatment of interest, depreciation, and capital gains; and the chance to acquire cheap federal lands whose market value will continue to appreciate. BLM's omission of these incentives recognizes that tax incentives are transfers and do not reflect economic productivity of the proposed development.

This article uses parametric budgeting to simulate the impacts of variations in farm size, crop prices, crop yields, electricity rates, lift height, and distance from the river on the private economic feasibility criterion currently being used by the BLM. Maximum feasible lift heights and carry distances are identified, and developable acreage is estimated. Using the criterion chosen by BLM, the acreage selected for development would exceed that which meets a social feasibility test because of the ignored social development costs. At the same time, the BLM approved acreage would fall short of meeting the development demand based on private financial accounting criteria. Since the BLM is using this compromise between a strict social and private accounting, some idea of the acreage which might be developed under this test is of considerable interest.

Simulation Procedures

Costs for owning and operating irrigation facilities were based on the use of sideroll sprinklers since they are currently, and probably will remain, the dominant system in the area covered by the BLM

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environmental statement. Specifying these costs so as to allow later parametric variation of power rates, lift, and distance means that a set of typical facilities rather than site-specific facilities had to be used. A hypothetical project containing 7,238 irrigated acres on benchland 550 feet above and 5 miles from the river was chosen as a benchmark. Typical pumping and application facilities were specified for the base system, and as parametric variables were changed from this base, required hardware changes and consequent cost changes were computed.

A computer program was developed to calculate required pumping horsepower and electricity use and cost. Calculations were based on monthly water needs for a typical crop rotation, and on irrigation efficiency, pump and motor efficiencies, lift and distance, sprinkler operating pressure, electric rate schedules, and pump-scheduling assumptions. Under base conditions, 18,000 horsepower would be needed for the primary lift and 6,270 horsepower would be needed at booster pumping stations to distribute water and pressurize sprinklers. Estimated costs (using 1978 prices) for pumping and delivery facilities for the base run are summarized in table 1. These approach $7.5 million, or $1,031 per irrigated acre. Spread over 7,238 irrigated acres and amortized at 8% for twenty-five years, this is $96.62 per acre per year. Sprinklers were assumed to come in replicates for 160 acres with 154 acres actually irrigated. An initial cost of $46,500, a 10% salvage value, and a twenty-year life resulted in annual on-farm system costs of $54.45 per irrigated acre. For the hypothetical base case, the computer program estimated power costs of $56.92 per irrigated acre using 1978 electric rates. The remaining cost item was $9.10 per irrigated acre for operation and maintenance of pumping and water distribution facilities. Total irrigation facilities and electricity costs for the base run were $217.09 per irrigated acre per year.

Returns were based on budgets prepared using the Oklahoma State Budget Generator (Walker and Kletke). Crop prices were an average of 1974–77 prices, and costs reflect 1978 conditions. Yields typical for class I and II soils in the study area were chosen. Three farm sizes—320, 640, and 960 acres—were selected as representative operating units under the acreage limitations imposed on public land disposal. The assumed rotation consisted of half wheat and half potatoes for the first five years, then equal parts of potatoes, wheat, and dry beans in later years. This rotation corresponds closely to actual practice in the area and to the rotation analyzed by BLM in their environmental statement. Table 2 shows net returns per acre for this rotation before subtracting cost of land, electric power, and costs of operating and maintaining water pumping and application systems but after subtracting farm overhead, owner labor, and an allowance for risk and management. The time stream of uneven returns was converted to a uniform stream of annualized equivalent returns using a twenty-five-year planning horizon and an 8% discount rate. The size economies evident in table 2 are due primarily to

Table 1. Annual Costs of Irrigation Facilities and Power for the Base Run

	Total Cost to Project	Annual Cost per Irrigated Acre
Project pumping and delivery system	($)	
River pumping plant	1,783,720	
Penstock	1,493,484	
Booster pumping plants	583,562	
Pipelines and farm turnouts	2,003,058	
Regulating reservoir	188,473	
Farm maintenance roads	427,556	
Land preparation	139,590	
Operation and maintenance equipment	150,913	
Electric power delivery facilities	495,000	
Other preproject costs	200,000	
Total cost	7,465,356	96.62
On-farm application system		
Interest on average investment		16.61
Taxes on average investment		1.16
Straight-line depreciation		13.59
Insurance on average investment		1.00
Repairs		7.51
Irrigation labor		14.58
Total cost		54.45
Electric power costs		56.92
Project operation and maintenance costs		9.10
Total irrigation costs		217.09

Table 2. Residual Annual Returns to Land per Irrigated Acre for the Base Run

	320 Acres	640 Acres	960 Acres
Returns to land, power, and irrigation facilities		($)	
First five years	319.45	333.72	344.74
Subsequent years	251.38	274.83	283.18
Level annualized return	276.85	296.86	306.21
Cost of power and irrigation facilities	217.09	217.09	217.09
Residual returns to land	59.76	79.77	89.12

the equipment sets selected. Larger farmers rely less on costly custom operations and make more efficient use of larger equipment items. Cost of power and irrigation facilities was subtracted from these net returns to give residual returns to land.

For development on public land, a nominal filing fee and grazing compensation are the only land costs. The undeveloped land is now used for low-density grazing. Hence, some "lost" grazing returns are an opportunity cost relevant to the social evaluation of irrigation development. However, the rancher grazing the land is rarely the person considering development. The Carey Act limits grazing compensation to a one-time, $6 payment per acre. Both grazing compensation and filing fees are part of the "preproject costs" shown in table 1. Without full compensation, any additional grazing opportunity costs are irrelevant to private development decisions. Any project with positive residual return to land after covering all other costs was judged to be feasible. Under the base conditions (1974–77 average crop prices, assumed yields, 1978 electric rates, 550 feet of lift, and 5 miles distance), all three farm sizes passed this test of private feasibility.

Sensitivity of Returns to Parameter Changes

The easiest parameters to vary are crop prices and yields. The assumed rotation gave a level annual equivalent gross return stream of $642.55 per acre. A 10% increase in either yield or price would raise this gross by $64.25. Since costs would be unchanged, residual returns to land would rise by $64.25. A price or yield decline of just under 10% would make the 320-acre farm size infeasible, while larger farms could endure reductions somewhat larger than 10%. Although crop prices are notoriously difficult to predict, the 1974–77 average prices and 1978 costs used in the base run seem to fairly represent the likely long-run relative levels of costs and prices.

Yields in the base run may be optimistic. They were based on five feasibility studies for projects in the study area and Soil Conservation Service estimates of yield capability.[1] The BLM environmental statement used yield estimates which averaged 9% below those used in the base run. Hence, results using base yields should be viewed as defining the outer limits of feasibility.

Parametric variation of electric rates followed a similar logic. Base-run electricity costs were $56.92 per acre. A 50% increase in both the energy charge and capacity charge elements of the rate schedule would boost costs and reduce residual returns to land by $28.46. All three farm sizes could endure a 100% rate increase, while the 960-acre farm alone remains feasible after a 150% increase. The 1978 electric rates used in the base run resulted in an average power cost of 1.5¢ per kilowatt hour. As load growth shifts the Pacific Northwest from heavy reliance on cheap hydroelectric power to more expensive thermal power, rates for Idaho irrigators are certain to rise toward the 4¢ to 6¢ per kilowatt paid by farmers in other parts of the country.

When lift height or distance from river are parametrically varied, the computer program calculates the new electricity cost and the change in pumping horsepower needed to meet the altered pumping requirements. The incremental cost of motors, pumps, penstock, closed delivery pipe, and associated facilities must be computed. With all other parameters at base levels, all farm sizes are feasible at 900 feet, the highest lift used. Likewise all farm sizes are feasible up to at least 10 miles from the river. Although the 900-foot and 10-mile figures may seem extreme, BLM is studying higher and more distant areas for possible irrigation development.

To appreciate the effects of the parametric variables, it is useful to vary jointly lift, distance, and rates, while price and yield are held at base levels. Results are shown in figures 1–3, where each X corresponds to a given lift, distance, and farm size. Feasible X's are located below and to the left of boundary lines which correspond to parametric electric rate levels. For example on a 640-acre farm, a 100% rate increase would leave farms 3 miles

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[1] The unpublished feasibility reports were prepared by engineering consultants hired by the project backers. The reports had to meet standards of credibility imposed by the Idaho Department of Water Resources and are now on file with IDWR. The proposed projects include Crane Falls, Indian Hills, Skyles, Narrows, and Bennet Mountain. SCS yield estimates for the study area were provided in June 1978 by Soil Conservation Service personnel, Boise, Idaho.

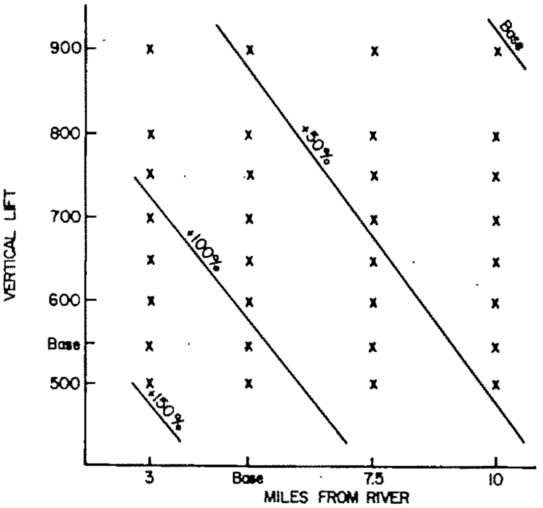

Figure 1. The effect of lift, distance, and electricity rates on project feasibility for 320-acre farms

from the river feasible if lift is 900 feet or less. Farms 5 miles away could lift water 750 feet. Those 7.5 miles distant have a feasible lift of only 550 feet.

This parametric procedure was used to evaluate the feasibility of irrigating lands identified in the BLM environmental statement, which lists developable acreage in the study area by lift and distance (BLM, page A-61). Of 111,015 developable acres, 108,381 have lifts and distances making them feasible as 960-acre farms under base conditions. If 640-acre farms were used, 107,453 acres would be developable, and 99,126 acres could be developed as 320-acre farms. As electricity rates increase above 1978 base levels, irrigation of more distant and higher lift lands is precluded, and total feasible acreage falls sharply (figure 4). If electric rates approach levels paid by irrigators in other parts of the country, development of most land in the study area would be precluded. However, there is likely to be pressure for more development than approved since the BLM criterion understates private profitability. This development pressure will be expressed even though the social feasibility of the development may not be demonstrated.

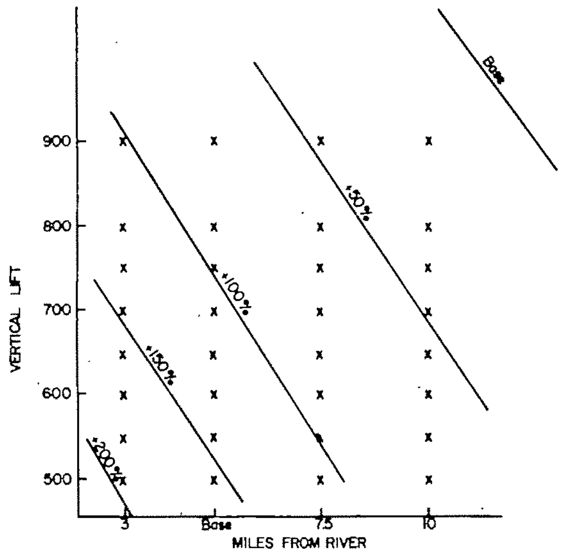

Figure 2. The effect of lift, distance, and electricity rates on project feasibility for 640-acre farms

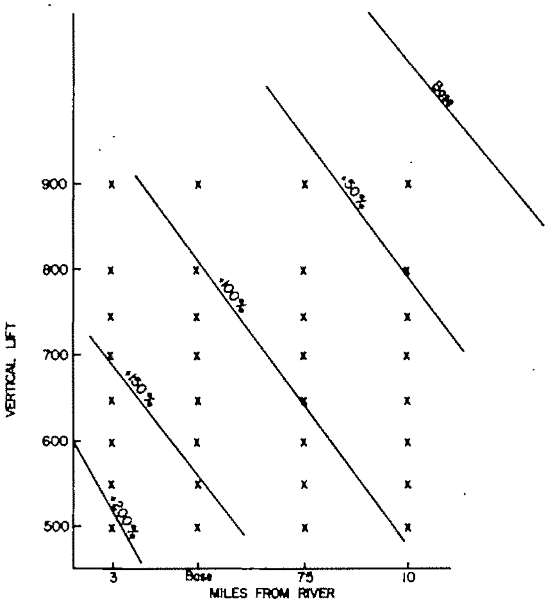

Figure 3. The effect of lift, distance, and electricity rates on project feasibility for 960-acre farms

Limitations of the Analysis

An obvious limitation of the parametric budgeting procedure is its omission of financial and tax incentives which may accrue to some operators. However, the purpose here is to model the criterion used by the BLM in evaluating development feasibility, a criterion which omits these incentives.

The model is also limited by its partial equilibrium nature. Figure 4 suggests that the acreage which can feasibly be developed decreases sharply with rate increases of 100%–200%. If higher power rates cause crop development to lag behind demand growth, crop prices will rise, improving the feasibility of development. Such a simultaneous model is beyond the scope of this paper.

This model did not allow for management options such as irrigation system alternatives or crop changes in response to higher electricity prices. A model incorporating the full range of substitution possibilities would be formidable and costly to construct compared to the limited impact of these ad-

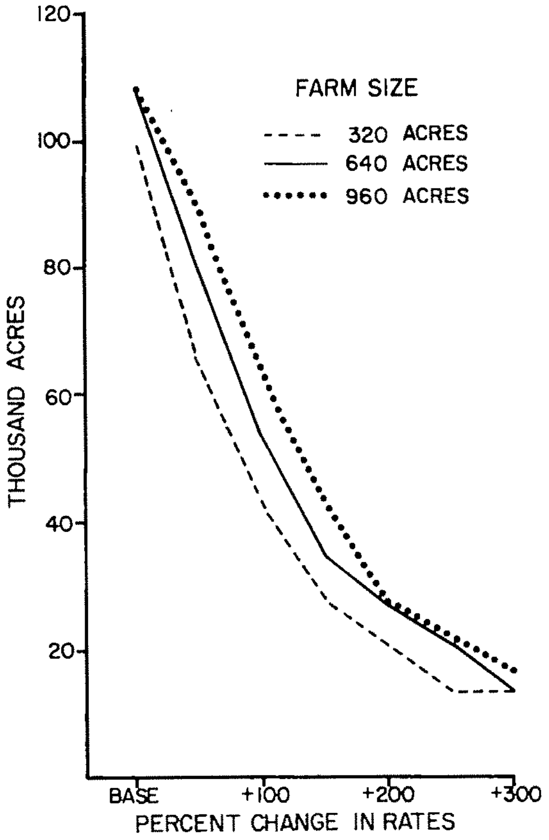

Figure 4. The effect of electric rate increases and farm size on feasible development acreage in the BLM study area

justments on estimated feasibility. For example, improved irrigation efficiency would reduce the volume of water needed and cut pumping costs. Switching from sideroll sprinklers with an assumed 70% irrigation efficiency to center pivot sprinklers at 80% efficiency would increase returns to land by only $1.57 per acre under base conditions and slightly more at higher elevations, greater distances, and higher rates.

As power rates go up, it is possible that less energy-intensive application systems may be sought. These include options such as automated gated pipe and pumpback systems, which substitute water, capital, and labor for energy. These two options typically have water application efficiencies less than or equal to sideroll sprinklers, meaning that as much or more water must be pumped from the river to the field. With sideroll sprinklers under base conditions, 71% of project electricity was used by primary lift pumps and only 29% by the on-farm application system. The proportion consumed by primary lift would be even higher as more distant and higher elevation lands are considered. Under such circumstances, on-farm energy savings would have little impact on total energy costs. On-farm savings could even be offset by increased pumping costs if application efficiency is impaired requiring more water to be pumped. Unless application system changes also save water, their effect on feasibility of high lift development will be minimal.

Potatoes have the highest water requirement of crops in the rotation. While deficit irrigation may have potential value for grains, the yield and quality declines which result for potatoes make this an unlikely method to save water or energy. Because potatoes are the highest value crop in typical rotations, development is infeasible if they are excluded. Therefore, significant changes in crop rotation to save water and energy in the face of higher energy costs are unlikely.

Conclusions

The model outlined in this paper gives a reasonable partial equilibrium simulation of the impact of critical parameters, such as crop prices and yields, electricity rates, lift height, and distance from the river upon feasibility of high lift irrigation development in southwest Idaho. Results indicate that per acre returns on irrigated tracts increase slightly with farm size. Under base conditions, all farm sizes examined could sustain nearly a 10% decline in crop price or yields. Given the base lift, 550 feet, and the base distance, 5 miles, all farm sizes considered could sustain a 100% increase in electric rates. However, with a 200% power rate increase, irrigation feasibility would be limited to the largest farms with lifts less than 550 feet and distances less than 4 miles.

Of the lands in the BLM study area, all but the highest and most distant could be developed under base yields, prices, and power rates. However, plausible increases in power rates could limit development to low lift land near the river, sharply reducing the total feasible acreage. The criteria being used by the BLM would permit development of more land than meets social criteria but not enough to meet private demands.

While the model developed in this paper and the conclusions derived from it are specific to the Pacific Northwest, the analytical approach has wider potential application. Moreover, the conclusions suggest responses that can be expected from energy-intensive agriculture in other regions as energy prices rise.

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Price Specification in Milk Supply Response Analysis

Richard A. Levins

During the 1970s, the Nerlove partial-adjustment model and the polynomial distributed lag model were often used in estimating milk supply response. Chen, Courtney, and Schmitz used a polynomial lag model to determine milk supply response in California with quarterly data. Hammond used both the Nerlove partial-adjustment model and a polynomial lag model with annual data to estimate milk supply functions for major U.S. producing areas.

In a 1978 study of the California dairy industry, Milligan rejected both lag specifications in favor of direct estimation of lagged profitability parameters. A bimonthly series of data on profit margins was used. In this paper, direct estimation of milk supply response coefficients is applied to a situation in which annual data for milk prices, but not profit margins, were available. The case study of milk production in Mississippi for the 1960–78 period gives additional evidence that the compromises inherent in specifying a priori patterns for lagged price parameters can be avoided if the parameters are estimated directly.

A Mississippi Case Study

During the past two decades, there was a general decline in Grade B milk production in Mississippi, but Grade A milk production remained relatively stable. Since Grade A milk accounts for almost all current production, only Grade A was considered in the analysis.

Of course, several nonprice factors determine milk production. Results of analyses not presented here indicated that production costs and technological change were most important in the case study. Mississippi production cost data were not available for the entire period. Therefore, the price of 16% protein feed was used as a proxy, since recent U.S. Department of Agriculture (USDA) estimates show that feed costs accounted for 55% of total 1978 production costs in southwestern Mississippi and southeastern Louisiana. A trend was used to reflect technological change.

A linear model of Mississippi milk supply response was formulated as follows:

$$(1)\quad Q_t = a + b_0P_t + b_1P_{t-1} + \dots + b_nP_{t-n} + c_1 FP_t + c_2t + U_t,$$

where Q_t is annual Grade A milk production (million pounds) in time t, reported by Trammell; P_t is the average price received for Grade A milk ($/cwt) in time t, as reported by Trammell and deflated by the producer price index; FP_t is the price of feed ($/ton) in time t, as reported by the Mississippi Crop and Livestock Reporting Service and deflated by the producer price index; t is time, $t_1 = 1960, \dots, t_{19} = 1978$; a, b's, and c's are parameters to be estimated; and U_t is an error term in time t. The expected signs for the coefficients of milk prices received are positive, negative for feed price, and positive for the time trend.

Theoretical Considerations

A price change will act in at least two separate ways to affect milk production. Short-run production changes can be made by culling herds and/or altering feeding practices. Long-run production increases require changes in herd size. If a model of quantity produced as a function of past prices is specified and estimated, one would expect recent prices to have a relatively strong effect. This would be followed by some "intermediate term" prices with relatively small effects because short-run changes had already been made and the effects of long-run changes were not yet felt. Then there would be some other relatively strong effects as herd size changes had their impact, after which more distant price effects would become negligible.

A relationship among the milk price coefficients in equation (1), consistent with this hypothesis, is shown in figure 1. There is one relatively strong effect associated with b'_t and a second with b''_t. But which are these two price coefficients? For b''_t, the answer is fairly clear—it corresponds to the time necessary to bring new cows into production. Estimates of two to four years, most commonly three years, have been made. However, for b'_t the answer is less clear. Is this the coefficient of the immediately preceding price, as is usually assumed, or the current price? Current price may be relevant with a data-reporting interval as long as one year because milk production is a continuous process.[1]

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The suggestions and comments of C. E. Powe, Y. N. Lin, M. R. Langham, and anonymous *Journal* reviewers are acknowledged.

[1] Normally, if supply and demand are determined simultaneously, single-equation methods would be inappropriate. However, since production in Mississippi is very small in relation to total U.S. production, simultaneous equation methods were judged unnecessary.

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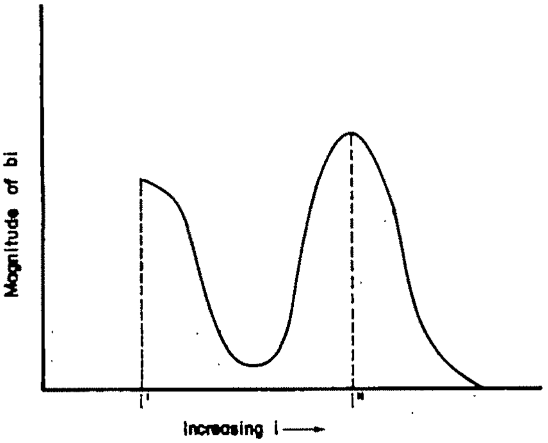

Figure 1. Hypothesized relationship among the milk price coefficients (*bi*) in equation (1)

While a soybean producer must wait until next year to plant a new crop in response to this year's price, the milk producer can make short-run adjustments in culling and feeding that can alter current situations.

Direct Estimation of Model Parameters

If the relationship among the milk price coefficients is similar to that in figure 1, the Nerlove model, in which expected price is represented "as a weighted moving acreage of past prices in which the weights decline as one goes back in time" (Nerlove, p. 499), is not particularly well-suited to milk supply response. While the polynomial lag model offers the theoretical possibility of approximating the expected pattern of lagged price parameters of figure 1, the simplifying assumptions of second-degree polynomials and endpoint restrictions used by Chen, Courtney, and Schmitz and Hammond effectively preclude such approximation.[2] For these reasons, along with inherent simplicity, the lagged price parameters were estimated directly.

There are two usual objections to directly estimating lagged price parameters. The first is that the price variables will be highly correlated, and the second is that the "direct approach" involves estimating too many parameters. With regard to the first objection, excessive correlation did not seem to be a problem with the data used here. Simple correlation coefficients among the lagged milk price variables ranged from .14 to .65. As for the second objection, the point of both partial adjustment models and polynomial lag structures is to reduce the number of parameters to be estimated. But, with annual data, certain polynomial lag specifications can require as many variables be estimated as does direct estimation. In any case, it is not altogether clear that the possibility of a small reduction in parameters to be estimated justifies the theoretical and statistical compromises inherent in these approaches.

Hence, the following equation was estimated using ordinary least squares:[3]

$$(2)\quad \begin{aligned} Q_t = -343.1 &+ \underset{(3.10)}{109.6P_t} + \underset{(1.36)}{53.2P_{t-1}} - \underset{(0.51)}{23.7P_{t-2}} \\ &+ \underset{(2.06)}{81.1P_{t-3}} - \underset{(1.93)}{2.11FP_t} + \underset{(2.83)}{4.72t}, \end{aligned}$$

where $R^2 = .86$, $DW = 1.65$, and $df = 9$. The signs of the feed price and trend variables were as expected, and both were significant at the .10 level (one-tailed tests). The price variables, however, are of most interest. Current price and P_{t-3} have coefficients significant at the .10 level, but the coefficients of P_{t-1} and P_{t-2} are insignificant. This pattern of the price coefficients is well in line with the relationship hypothesized in figure 1.

A second specification, in which the insignificant price variables from (2) were omitted, yielded the following:

$$(3)\quad \begin{aligned} Q_t = -375.0 &+ \underset{(4.73)}{129.3P_t} + \underset{(2.92)}{92.9P_{t-3}} - \underset{(1.75)}{1.76FP_t} \\ &+ \underset{(2.72)}{4.26t}, \end{aligned}$$

where $R^2 = .84$, $DW = 2.11$, and $df = 11$. With this formulation, t-values for the price variables were increased, but those for the feed price and trend variables were lowered.

With equation (2), the elasticity (measured at means) with respect to current price was .77 and the long-run elasticity, i.e., that for times t, $t-1$, $t-2$, and $t-3$, was 1.55. With (3), the corresponding values were .91 and 1.56. Milligan obtained estimates of .63 and 1.573 for relatively small dairies which predominate in Mississippi.

Concluding Remarks

Direct estimation of lagged price parameters in milk supply response models appears to have some advantages over commonly used distributed lag techniques. In return for a possible increase in the number of parameters to be estimated, direct estimation offers theoretical simplicity and the elimination of assumed a priori parameter restrictions.

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[2] See Schmidt and Waud for an excellent discussion of possible specification problems with polynomial lag models, especially those using endpoint restrictions.

[3] A similar model which included P_{t-4} was also estimated. Elasticity estimates were close to those presented here, but parameter significance was decidedly lowered by including the extra variable.

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Data Analysis with Computer Graphics: Production Functions

Ted F. Bay and Richard A. Schoney

Computer graphics provide a valuable addition to existing statistical procedures. While the usefulness of computer graphics in obtaining information on data or estimated response functions has been discussed (Cady and Fuller; Debertin, Pagoulatos, Bradford), comparatively little work exists on the application of computer graphics to analysis of research data and the subsequent development of useful functional forms. This paper proposes that computer graphics can be used with the traditional statistical tests of "goodness of fit" to promote a better understanding of data and aid in the selection of functional form.

When estimating functions, economic theory and a priori knowledge usually identify only general mathematical requirements which can be satisfied by numerous functional forms. Thus it is almost inevitable that estimated production functions contain some bias error. Cady and Laird demonstrate that misspecification by incorrect choice of functional form can be a major cause of bias error—the difference between the true model and the posited model over the area of interest. Measurement of the cost of bias error and its associated economic implications is of particular interest to economists. For example, Havlicek and Seagraves measured losses associated with suboptimal fertilizer rates resulting from misspecification. Computer graphics aid in analyzing and reducing bias error by providing direct insight into specific physical characteristics of data and functions.

This paper reviews the use of computer graphics as an aid in selecting functional forms to be used in fertilizer response analysis. Computer graphics can be used to develop response surfaces directly from experimental or nonexperimental data without restrictions on surface shape that are imposed by specific functional forms. Statistical models and an unrestricted "graphics" model are developed and evaluated by comparing potential losses due to suboptimal input recommendations.

Plotting Process

Graphic surface and contour plots are often used to study both physical and economic relationships. Examples include works of Anderson and Nelson and Heady and Dillon which incorporate two- and three-dimensional graphics to depict physical and economic characteristics of various functional forms. Production of graphics for teaching and research has been greatly simplified by computer-controlled plotting devices. Debertin, Pagoulatos, and Bradford demonstrated the potential value of computer graphics as an instructional aid for production economics courses.

Graphics demonstrated in this paper include data and function surface plots and their corresponding contour plots.[1] Surface and contour plots are generated from a rectangular data grid of X, Y, Z triplets, where X and Y represent the independent variables and Z is the dependent variable. Each set of X, Y coordinates represent one dependent variable value. For each X, Y combination, the dependent value is determined from the corresponding observation in the raw data set or, in the case of a mathematical function, directly from the estimated value. Where multiple dependent values exist for an X, Y coordinate in the raw data as a result of replicated or multiple observations, the dependent value may be specified as either the minimum, maximum, or mean value of the observations. The number of X, Y combinations in the data grid is user specified. This controls the degree of refinement exhibited in subsequent plots.

Analyzing Data

The use of computer graphics is demonstrated with experimental data from a 1977 corn fertility response study conducted at the University of Wisconsin Experimental Station at Arlington. The theoretical model for this study is

$$Y = f(N,K),$$

where Y is the yield of corn in bushels per acre, N is

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The authors would like to thank John F. Moncrief, Soils Department, for providing the example data; Richard M. Klemme, Rueben C. Buse, and two anonymous reviewers for helpful comments.

[1] The surface plots used here were generated by SURGEN, a three-dimensional, surface-generating routine, one of the Madison Academic Computing Center's (MACC) graphics routines. Contour plots are generated by CONTR, also one of MACC's graphics routines. Like SURGEN, CONTR produces plots either from user-supplied data or functions. The actual plotting is executed by a Zeta Model 3600-plotter.

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Table 1. Data Grid, Yield (Bushels per Acre)

Available Potassium (*K*) (lbs./acre)	Available Nitrogen (*N*) (lbs./acre)					
	75	131	187	243	299	355
388	78	153		184	172	189
357		144	167	166		175
325	90	141	184	192	178	170
294	103	148	185	179	181	175
262	109	152	167	186	168	182
231	112	150	172	186	181	176
199	88	164	193	161	170	164
168	97	157	155		150	

available nitrogen, and *K* is available potassium. Two hundred and twelve observations were used.

The example data were used to generate the 6 × 8 data grid shown in table 1. The mean value was used for *N*, *K* coordinates with multiple observations. Although not shown, a corresponding frequency table can be generated to show the number of observations at each coordinate. The data grid and frequency tables are important initial products of raw data plotting: they can be used to inspect large data sets for sampling irregularities, missing data, or lack of dispersion. Data and frequency tables also can guide improvements in experimental design and treatment levels.

Table 1 reveals several missing data points (or holes) in the data grid. Missing data points can cause distortion and ambiguities in subsequent plots. The surface plot and corresponding contour plot generated from the data grid are shown in figures 1a and 1b, respectively.[2] While the data plots do not present a smooth, continuous surface, they do depict important characteristics. Both the surface and contour plots suggest a continuous and rapid response to *N* up to approximately 180 pounds per acre where a yield plateau is reached. The location of global maximum is less clear. The dashed lines of figure 1b demarcate areas of missing data.

Clarifying Data Plots

Several graphics routines can be employed to improve the visual clarity of data plots by enhancing graphic definition, resolution, and intelligibility. A natural sequence is to (*a*) interpolate, (*b*) refine, and (*c*) smooth the dependent variable values of the data grid. Although these operations are independent of each other, their corresponding properties suggest the above sequence. Interpolation is a natural first step because, unlike the other two techniques, it can estimate missing data values. The primary purpose of interpolating at this point is to produce a complete grid of dependent values over the range of independent values. Interpolation also better preserves unique data characteristics as it moderates the influence of data irregularities.

Interpolation routines do not interpolate in the classical sense of linear interpolation but rather employ algorithms in estimating the dependent values of a data grid. Interpolation algorithms use the

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[2] The orientation of the *X*, *Y* axes is user specified. This particular representation was chosen because the primary interest was the response to nitrogen.

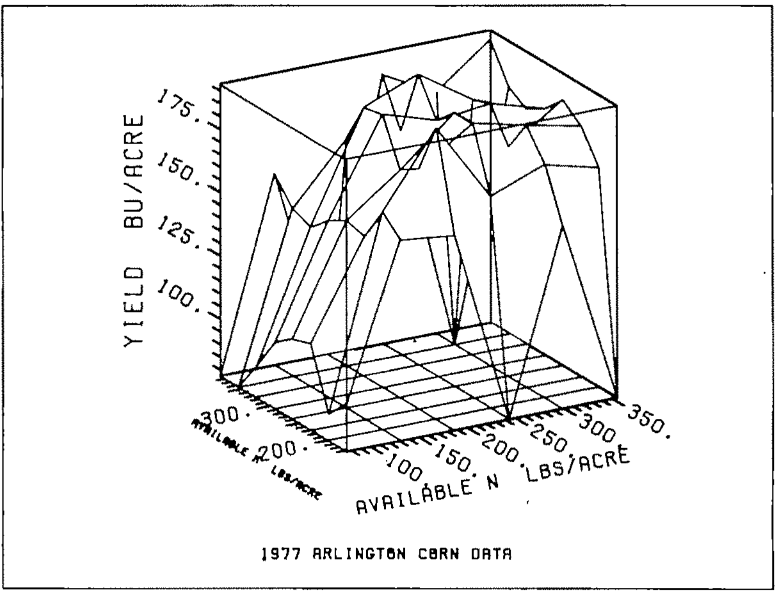

Figure 1a. Experimental data surface plot from 6 × 8 data grid

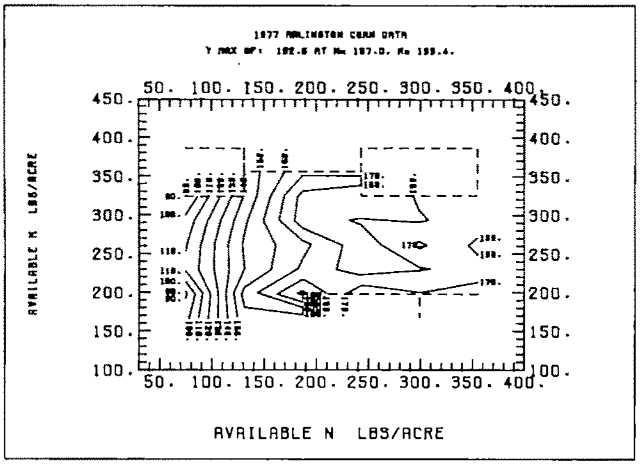

Figure 1b. Experimental data contour plot from 6 × 8 data grid

original data set to estimate new values at each X, Y coordinate location on a rectangular grid. Discussion of interpolation algorithms is provided in the Madison Academic Computing Center's (MACC) graphics manual *Two-dimensional Interpolation Smoothing and Refining*. A 6 × 8 data grid, interpolated from the 212 observations of the example data set, was used to generate the surface and contour plots in figures 2a and 2b. While figure 2b indicates the location of a global maximum, the somewhat jagged surface of figure 2a suggests that its existence is uncertain.

Refining and smoothing routines may be employed to create a more continuous surface. Refining generates a more detailed data grid by subdividing the cells (increasing the number of X, Y combinations) of the original grid. Dependent values of the new cells are determined from the original grid values through bilinear interpolation. Refining differs from the previous interpolation algorithms in that it retains the original grid values. The degree of refinement is user specified.

Smoothing modifies abnormally high or low values in a data grid. Each value in the grid is changed to the weighted average of itself and the nearby surrounding values by using either a standard set of weights or a user-supplied set. Smoothing may be repeated numerous times. In this example, the in-

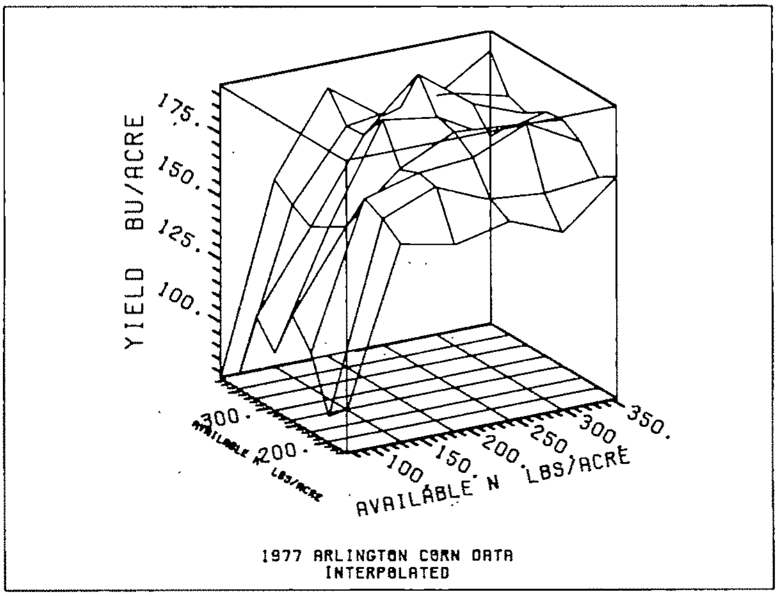

Figure 2a. Surface plot interpolated from 6 × 8 data grid

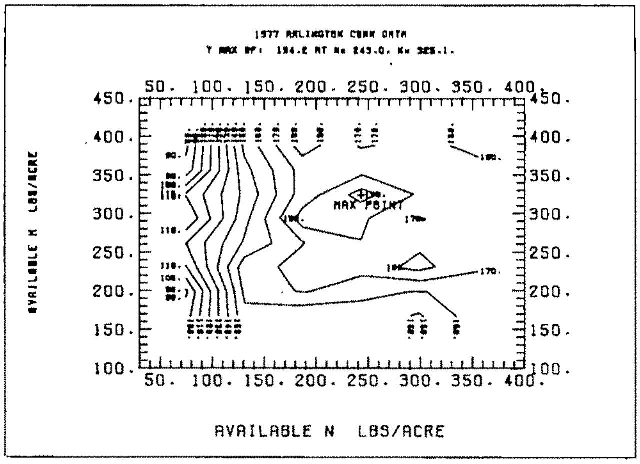

Figure 2b. Contour plot interpolated from 6 × 8 data grid

terpolated data grid was refined to the fourth degree (creating 16 cells for each original cell) and smoothed three times. The resulting surface and contour plots are shown in figures 3a and 3b, respectively. Both figures 3a and 3b suggest a yield plateau starting at N and K levels of approximately 180 and 225 pounds per acre, respectively. The contour map of figure 3b suggests a positive interaction between N and K at the higher yield levels.

Analysis of Estimated Response Functions

Three functional forms were selected to demonstrate the potential of computer graphics for comparing data and functions: the quadratic, the square root, and the translog (Heady and Dillon, pp. 73, 195; Berndt and Christensen). The equations, estimated from the example data set by ordinary least-squares regression, are equations (1.0) to (1.2), respectively.

$$(1.0)\quad Y = \underset{(.62)}{14.81} + \underset{(10.10)}{.7519N} + \underset{(2.40)}{.404K} - \underset{(-11.97)}{.001693N^2} - \underset{(-3.02)}{.000902K^2} + \underset{(3.48)}{.000645NK},$$

where $\bar{R}^2 = 67.1\%$;

$$(1.1)\quad Y = \underset{(-2.70)}{-233.12} - \underset{(-11.26)}{1.0645N} - \underset{(-3.06)}{.923K} + \underset{(7.38)}{25.02N^{.5}} + \underset{(2.30)}{23.1K^{.5}} + \underset{(3.84)}{.594N^{.5}K^{.5}},$$

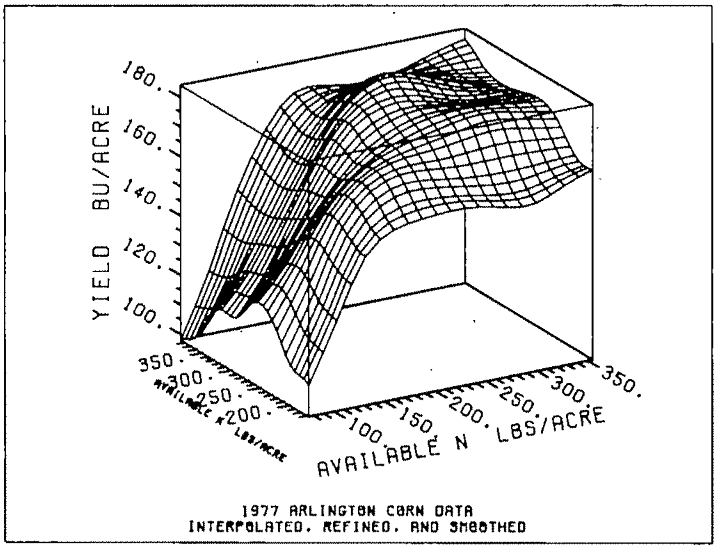

Figure 3a. Surface plot refined to fourth degree and smoothed three times

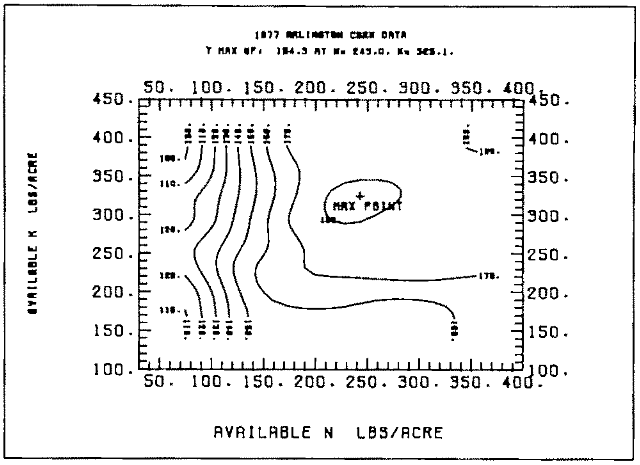

Figure 3b. Contour plot refined to fourth degree and smoothed three times

where $\bar{R}^2 = 70.5\%$;

$$(1.2)\quad \ln Y = \underset{(-1.81)}{-8.306} + \underset{(4.62)}{1.766}\ln N + \underset{(1.88)}{2.96}\ln K$$

$$\underset{(-10.49)}{-\ .276}(\ln N)^2 - \underset{(-2.67)}{.372}(\ln K)^2$$

$$\underset{(4.20)}{+\ .2349}(\ln N)\,(\ln K),$$

where $\bar{R} = 74.1\%$. (t-ratios are in parentheses.) The response surfaces and contour maps of these functions are shown in figures 4a through 6b.

Response surface plots prove particularly useful in the analysis of these functional forms. The translog model, for example, is an extremely flexible function with complex exponents which are functions of the independent variables. This makes it difficult to visualize an estimated surface without pictorial representation, especially the response characteristics and interaction between inputs. The surface plots also complement statistical analysis. The $\bar{R}^2$ of the translog model, when converted to a linear model, is 72.1% exhibiting a slightly better statistical fit than either the quadratic or square root model. The fit is further verified in subjectively comparing the data and estimated response surfaces: the translog model seems most nearly to match the data.

When interest is centered on a limited surface area, the plots permit a researcher to compare portions of the function and data plots without discarding any information. In our example, the area of most economic interest is between 180 to 240 pounds of available nitrogen (N) and 250 to 350

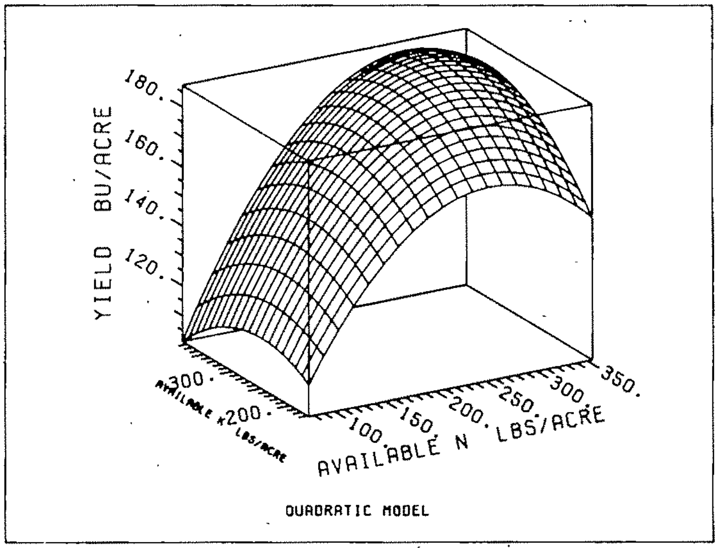

Figure 4a. Quadratic surface plot

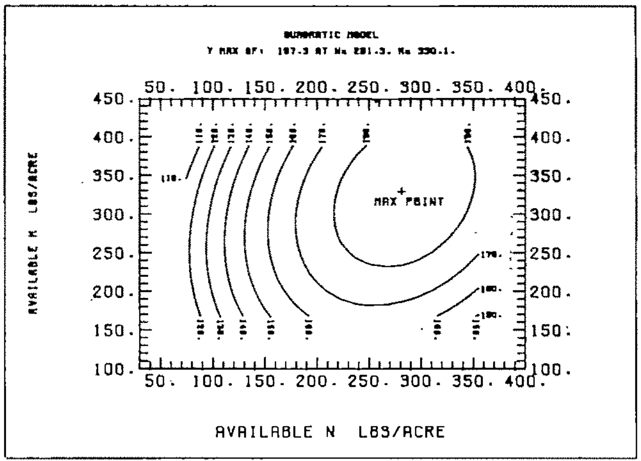

Figure 4b. Quadratic contour plot

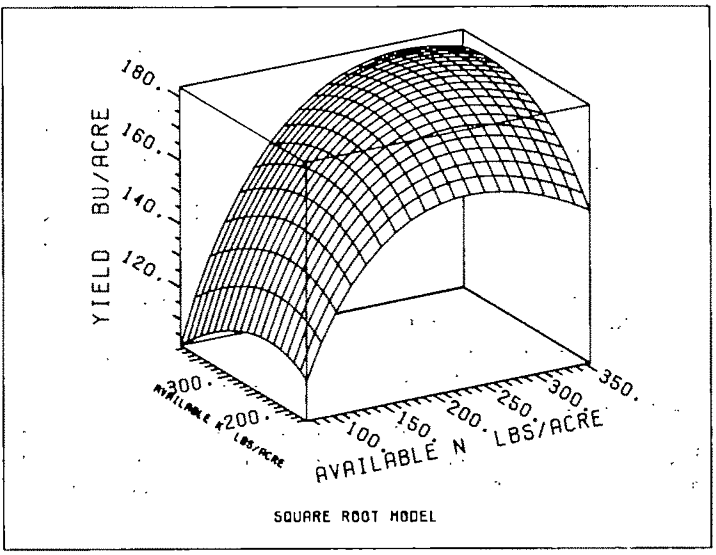

Figure 5a. Square root surface plot

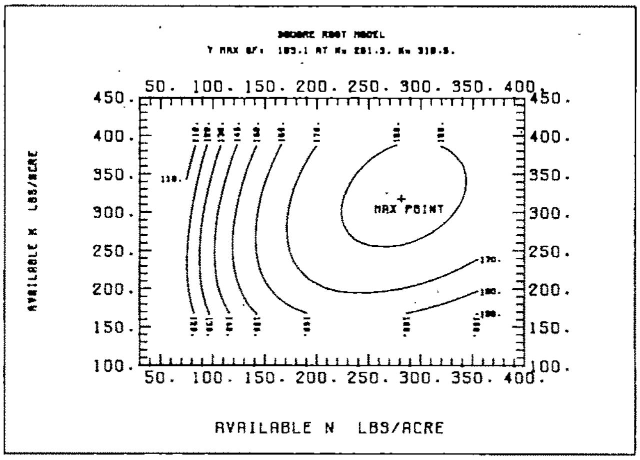

Figure 5b. Square root contour plot

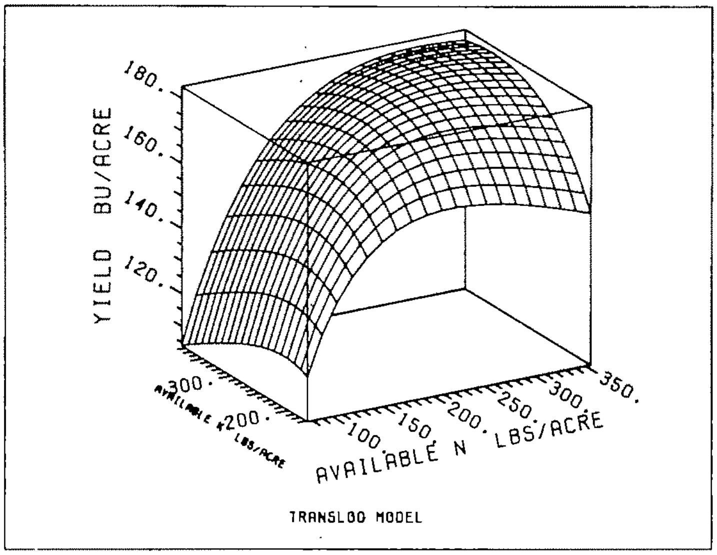

Figure 6a. Translog surface plot

pounds of available potassium (*K*) (based on rotation requirements). Within this area, all three models depict similar yields characteristics. The choice of best fit is unclear.

Economic Implications of Misspecification

If the "true" model is unknown, the data surface plot or "graphics" model can be a benchmark of comparison. While the graphics model has no known statistical properties, it places few a priori restrictions on the surface. Table 2 presents the optimum yield and input combinations suggested by the various models. Considerable differences in optimum input levels are displayed along with some yield differences. More important, however, are the differences between the graphics model and the statistical models. The graphics model generates similar *N* levels as the translog model but considerably higher *K* levels than any of the statistical models. This may be caused by one of the local

Table 2. Optimum Prodction and Input Combinations

	Optimum Level		
Model	N^a	*K*	Yield
	(lbs./acre)	(lbs./acre)	(bu./acre)
Quadratic	259	293	186
Square root	241	281	181
Translog	231	274	181
Graphics	229	317	184

Note: Based on the following prices: net price of corn, $2.40/bu.; nitrogen, $.15/lb.; and potassium, $.10/lb.

[a] Includes contributions from soil organic matter.

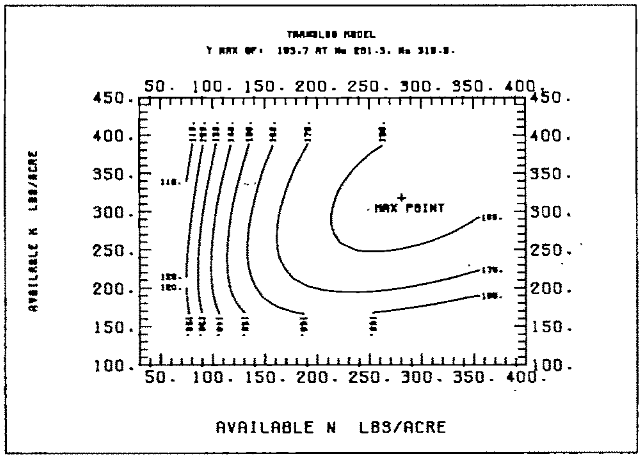

Figure 6b. Translog contour plot

Table 3. Cost of Being Wrong

	"True" Model			
Alternative Model	Quadratic	Square Root	Translog	Graphics
	($/acre)[a]			
Quadratic	0	.92	1.84	14.10
Square root	1.38	0	.30	10.20
Translog	3.27	.27	0	8.00
Graphics	7.18	4.66	4.81	0

Note: Based on the following prices: Net price of corn, $2.40/bu.; nitrogen, $.15/lb.; and potassium, $.10/lb.

[a] While yields in table 2 are rounded to the nearest bushel, the values in this table are based on yields carried to the nearest tenth bushel.

maxima in figure 3a which could confine economic activity to its nearby region.

The decision maker faces many uncertainties—including weather, uneveness of fertilizer application, and differing soil fertility levels. Since the true model is unknown, one method of further analysis is to analyze the selection of alternative models including the graphics model (Havlicek and Seagraves). In this method of comparison, a "true" model is selected and the optimum input levels associated with the alternative models are used to estimate yields in the "true" model. The net returns derived from the "wrong" model (net returns resulting from substituting the optimum input combination of the wrong model into the correct model) are deducted from the true net returns and labelled the "cost of being wrong." These "costs" are presented in table 3.

The "cost of being wrong" between the various statistical models is comparatively small, ranging from $.27/acre (square root and translog) to $3.27/acre (quadratic and the translog). As opposed to the comparison between statistical models, the graphic model generates considerably greater costs. The cost comparisons are not symmetric—the costs of being wrong are higher when the graphics model is selected as the true model than when the graphics model is the alternative "wrong" model. This results from the relatively smooth, flat surfaces in the economic areas of the statistical models as contrasted with the relatively steep local hills of the graphics model.

While the translog model does not incur the lowest cost of being wrong in the statistical model comparisons, it does compare the most favorably of the statistical models to the graphics model, table 3. The quadratic model does not possess such inherent flexibility but it also does not incur large costs except in comparison with the graphics model. The square root model incurs the least cost in the statistical model comparisons but incurs somewhat greater cost than the translog model in the graphic model comparison. While we do not advocate the graphics model for exclusive use, it is an unrestricted "picture" of the data and can serve as a useful basis in selecting a functional form to best represent the area of interest.

Further Advantages and Limitations of Computer Graphics

Computer graphics packages generally incorporate features which add to their usefulness. These include labeling, identification of extreme points, orientation and positioning of the axes, and multiple color selections. Micro- and mini-computers may also greatly enhance the visual effects through the use of color and motion. A primary limitation of computer graphics is its restriction to two independent variables. A second, less obvious, limitation is that data are often modified to fit discrete grid coordinates, resulting in plots that do not display actual observations. In addition, information may also be lost through over-use or inappropriate use of interpolation, refining, and smoothing techniques. Finally, a relatively large number of observations are required in order to produce a useful continuous surface or contour plot. A limited data set may require such a coarse plotting grid that subsequent plots do not depict true data characteristics. Although there are limitations to computer graphics, the plots are relatively inexpensive and readily obtained at most university computing centers. The cost of producing the surface and contour plots used in this study was approximately $1.00 each.

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Using the Semivariance to Estimate Safety-First Rules

Peter Berck and Jairus M. Hihn

Safety-first rules, common in agricultural and development economics, require probability mass estimates for the lower tail of the relevant distribution. An example of a safety-first rule is: Choose the fertilization level to maximize income subject to the constraint that there is a 5% or less probability of not being able to pay for the fertilizer from crop revenues (de Janvry). Safety-first rules are used by de Janvry, Nakajima, and Roumasset to analyze production decisions of low income farmers in developing countries. Wright provides an application to the nineteenth century cotton industry; Telser applies it to hedging; and Boussard and Petit use a safety-first model to explain cropping patterns. For a theoretical review of various safety-first rules, see Pyle and Turnovsky.

There are at least three methods to estimate the probability mass in the lower part of the revenue distribution. Although the best method is to use the observed frequency itself, often there are insufficient observations in the tails. A second method is to use an approximation function, such as the Edgeworth series of the Pearson system of distributions (Walsh). The third method, which requires the least information, is to use a Chebychev-type inequality.

There is a wide range of Chebychev-type inequalities. Chebychev's original inequality is

$$Pr[|x - E(x)| \geq k\sigma] \leq 1/k^2.$$

Given only knowledge of a finite variance and mean, it gives the smallest upper bound that can be placed on the probability of an outcome k standard deviations below the mean. This bound can be tightened by incorporating higher moments and knowledge of the distribution functions convexity or continuity (Walsh). In this note it will be shown that, by using the semivariance instead of the variance, a sharper bound can be placed on the area in the lower tail. This is especially useful when the underlying distribution is asymmetric.

Let x be distributed as F with mean Ex. Its lower and upper semivariances are defined as

$$\sigma^{2-} = \int_{-\infty}^{Ex} (x - Ex)^2 \, dF$$

$$\sigma^{2+} = \int_{Ex}^{+\infty} (x - Ex)^2 \, dF,$$

where σ is the standard deviation. From this, it follows that

$$\sigma^2 = \sigma^{2-} + \sigma^{2+}.$$

The semistandard deviations are denoted σ^- and σ^+. The Chebychev inequality in terms of the lower semistandard deviation is

$$\text{(1)} \qquad \Pr(x \leq Ex - m\sigma^-) \leq \frac{1}{m^2}.$$

The proof follows the proof of Chebychev's inequality using the variance.

Since

$$\sigma^{2-} = \int_{-\infty}^{Ex-m\sigma^-} (x - Ex)^2 \, dF + \int_{Ex-m\sigma^-}^{Ex} (x - Ex)^2 \, dF,$$

then

$$\int_{-\infty}^{Ex-m\sigma^-} (x - Ex)^2 \, dF < \sigma^{2-}.$$

The function $(x - Ex)^2$ is at least as large as $m^2\sigma^{2-}$ on the interval $(-\infty, Ex - m\sigma^-)$, so that

$$\sigma^{2-} > \int_{-\infty}^{Ex-m\sigma^-} (x - Ex)^2 \rightarrow T dF \geq m^2\sigma^{2-} \int_{-\infty}^{Ex-m\sigma^-} dF, \text{ or}$$

$$\frac{1}{m^2} \geq \int_{-\infty}^{Ex-m\sigma^-} dF = \Pr(x \leq Ex - m\sigma^-).$$

To see that the semivariance inequality is tighter than the variance inequality, let $m = k\sigma/\sigma^-$. Substituting for m in the semivariance inequality yields

$$\text{(2)} \qquad \Pr(x \leq Ex - k\sigma) \leq \frac{1}{k^2} \frac{\sigma^{2-}}{\sigma^2}.$$

Thus, the use of the semivariance improves the Chebychev inequality by the factor σ^{2-}/σ^2.

If the distribution is symmetric, then $\sigma^{2-}/\sigma^2 = 1/2$ and yields the result,

$$\text{(3)} \qquad \Pr(x \leq Ex - k\sigma) \leq \frac{1}{2k^2}.$$

However, the symmetry assumption is restrictive and likely to be incorrect (Day). Using the semivariance allows the data to speak for itself, depending only on the additional assumption that a finite lower semivariance exists.

To illustrate the extent of the improvement, we

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provide three examples in which our new variant of the Chebychev inequality provides bounds on anticipated losses from growing crops that are substantially tighter than those derived from Chebychev's inequality or even the symmetric version of Chebychev's inequality, equation (3).

The first case is the revenue of sugar beets in Kern County, California. Revenue was predicted from a regression of revenue per acre on a constant term and the dependent variable lagged one and two time periods. The data were from the reports of the Agricultural Commissioner of Kern County, California, for the years 1963–77. Because sugar beet prices were stabilized by the government during most of those years, the probability that revenues would fall below the mean was greatly reduced. The mean of the prediction for 1978 was $493 per acre, and the standard deviation of the prediction error was 128. The prediction error is composed of two parts. One involves the standard error of the regression and is computed from the residuals. The other is from errors in the estimated coefficients. Assuming that the errors in the estimated coefficients were symmetric, the computed ratio of prediction semivariance to variance was .18. Thus, the standard form of the Chebychev inequality gives the probability of making less than $237 per acre (an arbitrarily chosen low return) as .25; while with the assumption of symmetry, that probability would be .125. Using the semivariance inequality presented in equation (2) gives a probability of only .045 of making $237 or less per acre. In this case, the use of the semivariance inequality gives strikingly different results from those of the usual Chebychev inequality and leads to the correct conclusion that there was not much financial risk in the growing of sugar beets during 1963–77.

Our second example was drawn from Day's classic work on estimating yields of cotton, corn, and oats. He estimated the parameters of a nonstandardized beta distribution for his yield functions by the method of moments. We computed the variance from these estimates using standard formulas given in Johnson and Kotz. The semivariance and the probability mass in the lower tail were computed by numerical approximations using a trapezoidal rule in conjunction with Rhomberg's principle (Bauer). The distribution of cotton yields when 37.5 pounds of nitrogen are applied per acre provides the best example for our illustration. The mean yield is 1,656 pounds per acre; the standard deviation is 523; the semistandard deviation is 316. From these numbers, it is easy to calculate estimates of the probabilty of obtaining a yield of less than 1,133 pounds per acre. The standard version of the Chebychev inequality shows that the probability of achieving such a low yield is 1.0 or less, so it provides no information at all. Assuming symmetry and using the Chebychev inequality gives a probability of .5 or less. Our semivariance inequality gives a probability of .36 or less. By contrast, the probability of obtaining a yield that low is only .15 when estimated from Day's beta distribution. Day's conclusion that "decisions for maximizing profit or minimizing risk must be based not only on expected yields and variance but upon skewness as well" (p. 735) can be restated as: risk-minimizing decisions should not be based on mean and variance but, rather, on mean and semivariance.

Roumasset's *Rice and Risk: Decision Making among Low-Income Farmers* provides our third example. Roumasset tests whether farmers' behavior on small rice farms can be described by expected profit maximization when a specified chance constraint has been met. The chance constraint is that the probability of making less profit than required for subsistence is lower than a specified level. Roumasset estimates the chance constraint by using the frequency distribution from his sample. For Binan regime 2 with 60 pounds of nitrogen per acre, Roumasset (p. 151) estimates the probability of profit being one standard deviation below the mean to be .23. A symmetric version of Chebychev's inequality estimates the probability to be less than .5. Our version of a semivariance Chebychev inequality puts the estimate at less than .33.

This discussion clearly demonstrates that the upper bound on the probability of an outcome k standard deviations below the mean calculated from the semivariance can be a significant improvement over an upper bound based on the variance.

Because the semivariance of the sum of random variables is not a simple relation of appropriate semivariances and covariances, semivariance techniques are difficult to apply to multivariate problems such as whole-farm planning. Nevertheless, the potential gains to semivariance techniques justify their use.

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Determinants of Agricultural Economics Faculty Salaries

Josef M. Broder and Rod F. Ziemer

This note reports the findings of a general salary model developed to determine the relationships between agricultural economics faculty activities, research productivity, and financial rewards. Monetary returns to research, teaching, and grantsmanship are examined along with other factors which influence faculty salaries.

Survey and Data

In the spring of 1980, 500 randomly selected agricultural economists at land grant universities were asked to complete a pretested mailed questionnaire.[1] The questionnaire was designed to secure individual information and preserve respondent anonymity. The 311 returned questionnaires represented a response rate of nearly 60%. Two hundred and forty-one of the respondents held Ph.D. degrees. These individuals formed the sample for the following analysis.[2]

A Model of Faculty Salaries

The relationship among faculty resources, productivity, and rewards were examined in the context of a general salary model. In this study, individual faculty salary on a twelve-month basis was used to measure rewards. Explanatory factors related to academic salaries have been suggested in previous studies. Explanatory variables for our model are as follows.

Publications consisting of articles, books, and other publications have been found to be significant salary determinants (Tuckman and Leahey; Katz; Siegfried and White; DeLorme, Hill, Wood; Coffey). For this study, variables representing research productivity were computed on a total career basis (*PUBTOTAL*) and an annual rate of publications basis (*PUBRATE*) in separate model specifications. (The number of annual average publications was computed by dividing the weighted total career publications by years of professional experience.) The *PUBTOTAL* variable represents a weighted total of career publications computed according to the following weights: book = 5; *AJAE* = 2; national, regional, foreign, and international journals = 1; and experiment station and extension publications = ⅓. Although any weighting scheme can be considered arbitrary, the weights used in this study reflect the procedures and empirical findings of previous studies on economic faculty salaries (see Delorme, Hill, Wood; Seigfried and White; Tuckman and Leahey). The faculty member's rate of publication (*PUBRATE*) was computed by dividing *PUBTOTAL* by years of experience. A positive relationship was expected between publication output and salary.

Experience was defined as years of professional experience since earning a Ph.D. degree (*YEARS*). Previous studies show a positive relationship between experience and faculty rewards (Feber; Katz; Siegfried and White; DeLorme, Hill, Wood; Coffey).

Courses taught as an indication of teaching load was measured by the total number of graduate and undergraduate courses taught during 1979 (*COURSES*). Previous studies have indicated that research is ranked over teaching for promotion and salary determination (Broder) and that teaching is negatively correlated with salary (Coffey). Lower salaries among teachers may result from less professional recognition, lower opportunity costs, and less employment mobility than that associated with researchers.

Grants were measured by the total research funds obtained by the faculty member during 1979 (*GRANTS*) Since no distinction was made between individually and jointly obtained grants, reported figures cannot be interpreted as an accurate measure of individual grantsmanship. Research grants enhance the flexibility and productivity of research programs. Therefore, universities were hypothesized to encourage and reward grantsmanship.

Employment mobility was defined as the number of employment changes since earning a Ph.D. degree (*CHANGE*). Other studies have found employment mobility to be a significant positive salary determinant (DeLorme, Hill, Wood; Katz), supporting the idea that faculty who are mobile and willing to relocate generally do so for higher salaries. However, some faculty may move because

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[1] Respondents were selected at random from agricultural economics faculty listed in *Professional Workers in State Agricultural Experiment Stations and Other Cooperating State Institutions 1978–79.*

[2] The country was divided into the five major regions defined by Peck and Babb in a study of AAEA memberships. Regional aspects of the sample and further discussion of the data appear in Broder and Ziemer; and Ziemer, Broder, Spurlock.

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they cannot obtain tenure or contract renewal. Rank is measured by dummy variables. The variable *FULL* equals one if the faculty member has been promoted to full professor, but zero otherwise. Similarly, *ASSOC* equals one for an associate professor, but zero otherwise.

Results

Ordinary least squares was used to estimate separate salary models; results appear in table 1. The two estimated models differed only in the specification of the publications variable. Model 1 utilized the variable *PUBTOTAL*, while Model 2 utilized *PUBRATE*. Results for both specifications are reported in table 1.

With one exception, all estimated parameters in both models were statistically different from zero. The signs on the *PUBTOTAL* and *PUBRATE* coefficients in the two models were positive as expected. Based on the estimated coefficients for *PUBTOTAL* in Model 1 and the ad hoc weights associated with publications, additional career publications yielded the following estimated annual salary increments: $450 for a book; $184 for an *AJAE* publication; $92 for other national, regional, foreign, and international journals; and $31 for experiment station and extension publications.

The relationship between the rate of faculty publication and salary was measured in Model 2. The *PUBRATE* coefficient takes into consideration the time required to produce selected publications or the frequency of publications over time. For example, based on the *PUBRATE* coefficient of approximately $738 and the assumed weighting scheme, an *AJAE* publication produced every four years would realize $369 in annual salary or one-fourth of the annual increment of $738 × 2 = $1,476 associated with an *AJAE* publication produced every year over an individual's career. With four years of experience, an individual with two publications in the *AJAE* would realize an estimated annual salary approximately $369 more than that for a similar individual with only one *AJAE* publication. These returns to journal publications are consistent with previous estimates which range from $229 to $337 (DeLorme, Hill, Wood) and from $345 to $392 (Siegfried and White). Estimates of returns to books were comparable to those found in other studies (Tuckman and Leahey, Tuckman and Hagemann).

Table 1. Factors Associated with Differences in Salaries among Agricultural Economics Research Faculty, 1979

		Estimated Coefficients^{b}	
Variable Name	Mean^{a}	Model 1	Model 2
Dependent Variable			
SALARY	$31,436.87		
	($7,108.45)		
Explanatory Variables			
1. *INTERCEPT*		23,773.52	22,242.05
		(30.87)^{d}***	(25.48)***
2. *PUBTOTAL*	18.16	91.77	—
	(49.25)	(4.76)***	—
3. *PUBRATE*	1.50	—	737.65
	(2.26)	—	(3.02)***
4. *YEARS*	13.61	258.16	335.37
	(8.97)	(5.47)***	(6.92)***
5. *COURSES*	2.07	−474.90	−378.27
	(1.58)	(−2.59)***	(−2.08)**
6. *GRANTS*	$ 65,736.00^{c}	301.85	359.29
	($207,041.00)	(1.80)*	(2.18)**
7. *CHANGE*	.86	865.96	908.95
	(1.19)	(3.60)***	(3.83)***
8. *FULL*	.48	5,082.82	5,805.70
	(.50)	(5.16)***	(6.07)***
9. *ASSOC*	.27	1,072.78	1,646.56
	(.44)	(1.31)	(2.05)**
Number of observations = 222:	R^2 =	.64	.65

[a] Standard deviations in parentheses.

[b] t-values given in parentheses.

[c] Actual.

[d] Asterisks indicate: * significant at the $\alpha = .10$ level; and ** significant at the $\alpha = .05$ level; and *** significant at the $\alpha = .01$ level.

Referring again to table 1, each year of professional experience yielded an additional $258 or $335 for Models 1 and 2, respectively, while the number of courses taught yields a negative $475 or $378, respectively, in annual salary. These results do not necessarily imply that faculty are penalized for teaching. Teachers may simply receive smaller salary increments than researchers. Furthermore, competitive bidding among universities for research faculty relative to teaching faculty may partially explain these differences in salary increments.

As expected, a positive relationship was found between grantsmanship and salary. Each $100,000 increment in individual or shared research grants yielded an estimated $302 to $359 in annual salary for Models 1 and 2, respectively.[3] Considering employment mobility, faculty received an additional $866 or $909 in average salary for an employment change. Finally, promotion from assistant to associate professor was associated with a $1,647 or $1,073 career salary increment, and promotion to full professor yielded an increment of $5,083 or $5,806 based on the models estimated. Approximately two-thirds of the variation in salaries was accounted for by the explanatory variables in both models.

Summary and Conclusions

The reward structure for agricultural economics research faculty is instrumental in directing faculty resources and efforts. This process is not well understood. In this paper a model was developed to determine relationships between faculty activities and faculty rewards. Salary determinants identified in the study were publications, professional experience, teaching loads, grantsmanship, employment mobility, and faculty rank. Career and annual rates of return to selected publications were estimated.

An additional *AJAE* publication was estimated to yield an annual salary increment of $184, while an additional book was estimated to yield $460 in annual salary. Total returns to all publications were found to increase substantially as the annual rate of publishing increased. Grantsmanship, employment mobility, experience, and faculty rank were all found to be positive salary determinants. Perhaps disturbing but not surprising, teaching loads were found to have a negative effect on salary.

The results of this study, which are generally consistent with those of previous studies, support the notion that publishing is more highly rewarded than teaching. This study makes no attempt to judge the desirability of the present reward structure. However, our findings should remind university and faculty administrators that research appears to be important for professional advancement and that a sensible faculty appointment should allow time for research.

Katz has argued that the present general reward structure at major colleges and universities tends to encourage research, possibly at the expense of teaching quality. From this perspective, administrators who are sensitive to teaching quality may wish to encourage and support research in the area of new teaching methods.

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[3] Since no distinction was made between jointly and individually held grants in the sample survey questionnaire, the coefficients for the *GRANTS* variable indicate salary return to successful individual or shared grantsmanship.

Proceedings

Dynamics of the World Food Situation
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Third World Development: Food, Employment, and Growth Interactions

John W. Mellor

Over the next few decades an unprecedented number of people and proportion of the world's population will reside in countries passing through a development phase in which domestic demand for food grows at a high rate relative to domestic production of food. That phase is described by high per capita income growth rates in a context of low base incomes and rapid population growth. In this phase the innate difficulty for food production growth rates to keep pace with demand growth is enhanced by the still immature system for shifting agricultural supply schedules which is characteristic of this relatively early stage of economic growth.

A substantial proportion of the population now experiencing accelerating economic growth falls in countries which derive a major portion of income from exports of oil, but increasingly the source is greater resource productivity through economic development and technological change. The latter is the result of the past few decades of concentrated effort to lay the institutional and physical infrastructure of a modern economic system.

Rising real food prices caused by greatly accelerated growth in demand for food will tend to restrain growth in developing countries and increase relative and absolute poverty. The extent of real price increase for food will be substantially determined by the rate of technological change and supply elasticity in developed countries. This is because in the developing countries Says law tends to operate in the market for food, and so accelerated growth in food production tends to create a roughly commensurate, or even greater, increase in demand for food.

In this context, it becomes economic for developing countries to place a greater emphasis on agricultural production in their development strategies than was justified in earlier decades. Success in such an effort will diffuse the benefits of growth more widely than alternative strategies and will even accelerate growth if, as has often been the case, previous emphasis on agriculture was suboptimal for the earlier conditions. Thus, over the next decade the economic pressures on the food front may well have a salutary effect on the pace and pattern of development.

The Extent and Sources of Accelerated Growth in Demand for Food

More than 700 million people live in third world countries which averaged growth rates of nearly 4% or better in per capita income for the period 1970–77.[1] Eight major oil-exporting third world countries (Algeria, Indonesia, Iran, Iraq, Mexico, Nigeria, Saudi Arabia, and Venezuela) had an aggregate population in 1977 of 361 million and an average per capita income growth rate of 5.6% per year. Twelve third world countries which are not major exporters of oil (Brazil, Hong Kong, Democratic People's Republic of Korea, Republic of Korea, Malaysia, Philippines, Singapore, Syria, Taiwan, Thailand, Tunisia, and Turkey) also had an average growth rate of per capita

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[1] Data cited in this section are adapted from a forthcoming paper by Mellor and Paulino (1982).

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income of 5.6% for the same period and an aggregate population of 349 million people. In such sets of countries one can expect demand for food to grow at well over 5% per year. Judging from historical records, it is unlikely that food production growth rates will match that pace.

Because of high rates of increase in export prices, the major oil-exporting countries have experienced a large growth rate in national income relative to their stage of development. In the short run this has caused sharp increases in savings rates and growth in foreign exchange balances. This suggests that rapid growth rates in consumption will be maintained even if real oil prices were to increase little over the next several years. In general for these countries, the institutional structure for accelerated growth in agriculture is underdeveloped relative to the growth rates in demand for agricultural commodities. Thus, in the period 1970–77 food imports to these countries grew at a rate of 19% per year in real terms.

Increased productivity of domestic resources is the primary source of growth in the second set of high-growth countries, although some have benefitted from substantial labor exports, e.g., Syria and Turkey. Without large improvement in barter terms of trade, rapid growth in overall income is difficult to achieve in countries with a large agricultural sector without participation of that sector in productivity growth. Thus, countries growing on the basis of increased efficiency have a closer balance between growth in demand for and supply of food. Nevertheless, with a growth rate in demand for food of well over 5% per year, net food imports are bound to grow, if not for every country in the group, then at least for the collectivity of these countries.

It is notable that the sixteen developing countries with the fastest growth rates in the basic food staples production collectively increased imports of basic food staples (Bachman and Paulino). The reference period for the study is 1961–76. Net imports (in tons) of basic food staples more than doubled for this set of food production successes, while the self-sufficiency ratio declined two percentage points. The average growth rate for basic food staples for this set of countries was 3.9%. The lowest was 3.25%. These data also demonstrate that it is remarkable for countries in a high growth rate phase of economic development to achieve growth rates in basic food staple production commensurate with rates of growth in demand for food.

What are the prospects that the 700 million people in the set of fast-income-growth countries will enlarge over the next few decades? Oil prices may not rise as rapidly as in the 1970–77 period, but consumption expenditures may in the future rise faster relative to total income. Some of the countries experiencing fast growth in productivity may falter from economic or political imbalances. On the other hand, other countries could well enter this class in the next decades. It is well to remember that as recently as the mid- to late 1950s both Taiwan and South Korea were widely considered to be poor prospects for growth, particularly given their poor export performance!

India is a massive and relevant case in point. The shift of India, with a population of over 700 million, to high growth status would have a significant effect on global aggregates. Linear projection of 1966–77 growth rates to the year 2000 brings India to the position of a significant net exporter of basic food staples. That is consistent with India's shift from a typical four to six million tons of imports in the 1950s and 1960s to a slight export position in the late 1970s, as well as with the evidence of India having institutionalized a somewhat accelerated food grain production growth rate with good prospects of a modest further acceleration of that growth rate. However, such projections ignore the extent to which India has simply shifted from food grain imports to vegetable oil imports. And more important, it ignores the fact that India's reduction of food grain imports is as much a phenomenon of decline in demand growth rate as of a rise in production growth rate (Mellor 1976). Or, more dramatically, it is a function as much of failure of nonagricultural growth as a success in agricultural growth. Achievement of the 10% growth rates in other sectors consistent with India's institutional structure would be consistent with a close to 4% growth rate in per capita income and, hence, in an over 4% growth rate in agricultural consumption—a demand growth rate well in excess of the current agricultural production growth rate (Mellor 1976).

Phases in Agricultural Demand-Supply Growth

The passing phenomenon of rapidly growing developing country imports of food is captured in table 1 which presents hypothetical data consistent with successive phases of income growth. The table, depicting five phases, shows accelerating growth in demand to a peak and then diminution. Net imports can be expected to grow as agricultural growth lags in its acceleration behind demand growth. The institutionalization of that growth can be expected to maintain the production growth rate despite decline in the demand growth rate, generating exportable surpluses. This pattern is consistent with the rapid growth in net imports of food by the current fast growth countries, with the finding that the fast-agricultural-growth developing countries increase their net imports of food and with exportable surpluses generated in the mature, high income countries of Europe and North America.

Row one of table 1 depicts an early stage of economic growth in which people are very poor, desperately wish to consume more food but cannot because their incomes are rising little if at all. Poverty causes high death rates and, hence, only modest rates of population growth. The result is a 3% or less growth rate in effective demand for food—a rate that the enlarging labor force, derived from population growth, may roughly provide by more effort on existing and added farmed area.

As development occurs, the population growth rate increases. But, even more important, income begins to grow more rapidly. The low base income carries a relatively high income elasticity of demand, and so rising income strongly augments the effect of population growth to increase the growth rate of demand for food by some 30% over the earlier phase and to exceed all but the most rapid known rates of food production growth. To maintain food production growth rates as high as 4% in general requires large unexploited land areas and institutionalization of continuous substantial improvement in technology.

Continuing progress of development further accelerates income growth. Even though the population growth rate may decline and income elasticity of demand drops significantly, the effect of high income growth is so overwhelming that the rate of growth of demand may well rise by another third. That rate surpasses all but the most extraordinary of past experiences with food production rates. It is this stage that so many countries encompassing large aggregate populations are now entering.

Eventually, of course, population growth rates decline to low levels, and income elasticity of demand for food becomes highly inelastic, and hence growth in income begins to have little effect on food consumption. Meeting demand growth not only becomes much more manageable, but food production growth rates may by then have become institutionalized at close to the high levels needed to meet past demand growth rates. It is in this phase that surpluses accrue. The argument is that in the next few decades a high proportion of the world's population will be in the high demand growth phase, and only a small proportion in the high income, low demand growth phase.

Population Growth

The effect of population growth on demand for food requires clarification because of its interaction with both supply and with other demand factors. Although income growth will be the dynamic force in causing rising food demand in the next decade, population growth will play an indirect role in forcing transfer payments and in interaction with income growth. Population growth will also enlarge the number of people in absolute poverty and deficient in food.

It is not an accident that food production

Table 1. Comparison of Growth of Demand for Agricultural Commodities, Hypothetical Cases

Levels of Development	Percentage of Population in Agriculture	Rate of Population Growth	Rate of Per Capita Income Growth	Income Elasticity of Demand	Rate of Growth in Demand
Very low income	70	2.5	.5	1.0	3.0
Low income	60	3.0	1.0	0.9	3.9
Medium income	40	2.5	4.0	0.7	5.3
High income	30	2.0	4.0	0.5	4.0
Very high income	10	1.0	3.0	0.1	1.3

Source: adapted from Mellor 1966, p. 78.

growth in low income, agriculture-dominated countries keeps rough pace with population growth. Population growth enlarges the rural labor force and hence the capacity to produce food. If mounting pressure on land resources reduces labor productivity, per capita income declines and per capita food consumption decreases comparably. Income-depressing effects may be reduced by longer working hours or by reduced production and consumption of nonfood goods and services.

Decline in rural incomes from population growth may push more rural youth into urban areas, increasing urban unemployment and depressing urban wage rates. The resulting national political pressures may then cause governments to provide transfer payments to lower income urban people through food subsidy and distribution programs. Foreign assistance programs, motivated by concerns for equity or political stability, may relieve the foreign exchange burden of consequent food imports. Such foreign assistance, interacting with rapid population growth, may be an important source of growth in demand for food in the next decade in low income countries not yet experiencing rapid growth in productivity and income. Thus, countries which would not otherwise be expected to become major food importers may become so, adding further to the net food imports of third world countries.

When an economy undergoes sectoral transformation, with capital formation and technological change occurring rapidly in the nonagricultural sector, rapid population growth fuels that process. The supply of labor for growth of the nonagricultural sectors is in effect highly elastic. Under those circumstances of rapid growth in capital stock and labor force, the supply of wage goods—primarily food—will be the operable constraint to growth (Lele and Mellor 1981). Unless rapid technological change in agriculture occurs, the growth momentum can be sustained only by rapid growth in exports or foreign borrowings to pay for rapidly growing food imports. If rapid technological advances occur in agriculture, the extent of upward pressure on food prices is then the product of complex relations between the rate and nature of technological change in agriculture and the rate of growth in nonagricultural employment and income (Lele and Mellor 1981). Rapid application of modern high-yield agricultural technology will tend to restrain the rise in agricultural prices. Large capital transfers, including higher oil revenues, will have the opposite effect. Throughout these processes of rapid economic growth, the higher the population growth rate the greater the growth rate in demand for food.

There should be no misunderstanding about the deleterious economic effects of rapid population growth simply because the effective demand for food keeps roughly in pace with supply in early stages of growth or because in later stages it eventually encourages faster overall economic growth. Rapid population growth tends to decrease labor productivity in agriculture, reduce the pace of transformation of the economy from agricultural to nonagricultural, and hence, discourage growth in per capita income, in food intake, and in nutritional status. Its burden falls on the poor, whose income is derived solely from labor.

Income Growth

Accelerated growth in income is the basic source of divergence in growth in demand and supply of food. The extent to which income growth accelerates food demand growth beyond food supply growth depends, on the demand side, upon the level of income, the employment content of growth, and the rate of income growth itself. The first two factors affect the aggregate income elasticity of demand. Demand will be driven rapidly when income is initially low, when growth has a high employment content, and when the income growth rate is rapid. Large net capital inflows and enhanced terms of international trade favor the latter. Because of strong multiplier effects of agricultural growth, heavy investment in agriculture may not shift supply of food more rapidly than demand.

It should be noted that inelasticities of agricultural supply with respect to increased demand traces to the fixity of land resources and hence are phenomena of the basic food staples such as cereals, which use the bulk of land. As demand for agricultural commodities rises in response to income, the relative composition of demand changes. It is fruits, vegetables, and livestock products for which demand is more elastic and it is the livestock commodities which are most important in aggregate. They represent a potentially large, derived demand for basic food staples or the production resources for basic food staples, particularly at the margin. And, it is the rising importance of livestock products that plays a major role in restraining the decline in the overall income elasticities for basic food staples. Income elasticity of demand for livestock products remains relatively stable at well over one, up to income levels still achieved by only a handful of countries.

A peculiarity of the derived demand for feed for livestock should be noted. At low incomes, livestock comprise a small budget share, and hence the derived demand for basic food staples is small. As incomes rise, the income elasticity of demand for basic food staples for direct human consumption declines; the income elasticity of demand for basic food staples derived from livestock consumption is much higher than that for direct consumption and declines less rapidly. The base level of the derived demand is very small relative to the direct demand, but, with sharply different elasticities the weights change rapidly, and the weighted average elasticity changes—at first declining, then rising, and eventually declining again. It is the period of rising weighted income elasticity of demand when demand growth for basic food staples increases explosively, tending to throw countries onto the international market for substantial aggregate imports of food.

Some Empirical Evidence

Table 2 provides data consistent with the foregoing analysis. The slow growth countries with less than 1.0% per capita income reflect rapid increase in imports because of large foreign assistance. They are largely concentrated in Africa, which receives per capita levels of foreign assistance which are large by historical standards of Asia. The somewhat faster growth countries (3.0% to 4.9%) evidence rapid growth in net imports as expected. The very fast growth countries (over 5%) show explosive growth in net imports for all the reasons indicated plus the loading of those countries in the oil-exporting categories for which incomes grow rapidly relative to institutional development and, hence, capacity to accelerate growth in agriculture.

Table 3 shows growth rates for basic food staples for each per capita income class. As expected, the basic food staple production growth rate is successively greater for each successively higher income growth rate, except for the fastest, which is, as stated, heavily influenced by the oil exporters. The relative importance of yield increase relative to area expansion also increases with per capita in-

Table 2. Exports, Imports and Net Trade of Major Food Crops in the Developing Countries, 1961/65 and 1973/77 Averages

	Exports			Imports			Net Trade[a]			Annual Growth Rate 1961/65–1973/77[b]	
Country group	1961/65 (million tons)	1973/77 (million tons)	Change[b] (%)	1961/65 (million tons)	1973/77 (million tons)	Change[b] (%)	1961/65 (million tons)	1973/77 (million tons)	2000[d]	Exports (%)	Imports (%)
Total	21.9	28.3	+29	27.2	51.3	+88	−5.3	−23.0	−125	2.1	5.4
By GNP/capita[c] growth rate											
Less than 1.0%	2.2	1.2	−47	3.8	9.2	+143	−1.6	−8.0	−46	−5.1	7.7
1.0%–2.9%	13.2	16.4	+24	10.4	15.3	+47	+2.9	+11.1	+18	1.8	3.3
3.0%–4.9%	4.1	7.2	+76	5.8	11.2	+93	−1.7	−4.0	−34	4.8	5.6
5.0% and over	2.5	3.5	+41	7.2	15.6	+116	−4.7	−12.1	−63	2.9	6.6
By region											
Asia	7.6	10.2	+34	13.9	21.2	+52	−6.3	10.9	−2	2.5	3.5
North Africa/ Middle East	1.4	1.1	−21	5.0	11.6	+133	−3.6	−10.6	−63	−2.0	7.3
Sub-Sahara Africa	2.9	1.7	−43	2.0	4.5	+127	0.9	−2.9	−29	−4.6	7.1
Latin America	10.0	15.3	+53	6.3	13.9	+122	+3.7	+1.4	2	3.6	6.9

Source: Developed by Leonardo Paulino from FAO.

Notes: Trade data include bran and cakes for feed use; to minimize double counting, partial adjustments were made for wheat flour based on available figures for this commodity as reported in the 1978 FAO *Trade Yearbook;* the People's Republic of China is not included in this table because of difficulties of developing significant trend coefficients in the face of large politically related fluctuations.

[a] Exports minus imports.

[b] During the period 1966–77.

[c] Calculated between the mid-years of the indicated periods.

[d] Projections derived from production and income data for 1961–77 and UN population projections.

Table 3. Average Annual Growth Rates of Production, Area Harvested, and Output per Hectare of Major Food Crops in the Developing Countries, 1961–77

Country Group	Average Annual Growth Rate, 1961–77			Relative Contribution to Production Growth	
	Production	Area Harvested	Output per Hectare	Area Harvested	Output per Hectare
	(%)			(%)	
Total	2.65	1.00	1.64	38	62
By GNP/Capita Growth Rate[a]					
Less than 1.0%	1.30	0.64	0.66	49	51
1.0%–2.9%	2.91	0.79	2.10	28	72
3.0%–4.9%	3.03	0.95	2.05	32	68
5.0% and over	2.75	1.89	0.85	69	31
By region					
Asia	2.78	0.66	2.10	24	76
North Africa and Middle East	2.53	1.12	1.40	44	56
Sub-Sahara Africa	1.59	1.28	0.31	80	20
Latin America	3.22	1.78	1.41	56	44

Source: Developed by Paulino from FAO.
Note: Excluding China.
[a] During the 1966–77 period.

come increase, again, with the expected exception of the highest income growth rate group and its oil exporter influence.

Global Effects of Accelerated Income Growth

The problem for world agriculture in the 1950s and 1960s was large populations in the very high income phase generating surpluses and a huge population in the very low income phase with slow growth in effective demand, despite the poor nutritional status of people in those countries. The high income countries attempted to restrain agricultural production and to develop systems to subsidize exports to low income countries with highly elastic demand. The low income countries showed a major interest in expanding industrial production.

The food problem for the world in the 1980s and 1990s is one of vast populations moving into the high growth, medium income stage, sorely taxing the export capabilities of the more mature economies. During this period of rapid growth in demand for food, problems of instability in food production will be particularly onerous.

Thus, the closing of the twentieth century will see a period of great pressure for developing countries to increase food production so as to minimize their need for imports of food, and for the developed countries to increase production to meet the inevitable increase in import needs of the developing countries.

Prices

The extent to which real food prices increase over the next few decades will be substantially determined by the relative size of the third world population which moves into the fast economic growth phase and the effective supply elasticities for food of the mature economies.

For the developing countries, their growth rates in agriculture will be more important in affecting their overall growth rates than in affecting the food supply-demand balances. That is because of the multiplier effects of agricultural growth in other sectors and the reinforcing effect of exogenous capital inflows that add further to demand stimulating growth (Mellor 1976; Mellor and Lele 1978, Lele and Mellor 1981).

The major exception to this generalization is the lowest income countries, for which failure in agriculture may be covered by politically or humanely motivated foreign assistance to maintain consumption growth rates ahead of population growth. Thus, growth in food imports is likely to be significantly restrained by production success only in the case of noncommercial imports.

For the developed countries, the critical issues are the extent to which rapidly expanding export markets will sustain or accelerate development and application of new production technology and the elasticity of area under cultivation with respect to real food price. High rates of technological advance and high supply elasticity of area will result in only small price increases in the face of large growth in third world imports.

Growth

If the real price of food rises substantially, it will slow third world growth through two important effects. It may reduce savings rates if governments feel pressure to maintain food consumption growth in the face of higher real prices of imported food. It will push up the real price of labor in terms of industrial goods and foster substituting capital for labor. The consequent capital deepening will raise incremental capital output ratios and slow growth (Lele and Mellor 1981).

This latter argument can be turned around to emphasize the role of accelerated growth in agriculture in facilitating mobilization of labor in a situation of rising real price of imported food. Thus, a rational response to the regime of the 1980s and 1990s is increased emphasis on agriculture's role in growth as compared to the 1950s and 1960s.

Poverty

It is the poor who will bear the burden of rising real prices of food (Mellor 1978). They will do so either in the form of reduced purchasing power from higher real prices of food or from lower employment due to food price induced increase in wage rates expressed in terms of labor product and consequent capital deepening.

Under these circumstances, concern for poverty alleviation focuses on means of expanding the supply of food. That may occur by facilitating the processes of technological change in the agriculture of developing countries, which facilitates growth in employment and food consumption even though it may not lead to greater food self-sufficiency. Growth in agricultural output in the mature economies can also facilitate increased welfare of the poor by relieving the upward pressure on real food prices and providing a basis for subsidized food for low income groups. The latter facilitates direct increase in welfare as well as increased employment through the effective wage subsidy.

Conclusion

The next few decades will be extraordinarily dynamic in food production, consumption, and trade. Increased food production in both developing and mature economies will become more central to both growth and equity strategies.

In this dynamic context new relationships will occur among various food-related factors, presenting new challenges and additional responsibilities on the research community. It is already clear that research is needed to trace the course of derived demand for basic food staples from the complex changes in consumption patterns that accompany rapid income growth. The relationship between employment growth and food supply needs to be explored in all its ramifications, including the marginal propensities to spend wage income on food, the elasticities of substitution between food and other goods and services, the respective supply elasticities of those commodities, and the elasticities of substitution of capital and labor in various production processes. These are all of direct and interacting relevance to the demand for food and the extent to which food supply may restrain economic growth. The nature of the labor market more generally needs exploration, particularly as it affects the balance between food production and income generation in other sectors—a relationship particularly important and poorly understood in African countries (Lele 1975). Finally, the optimal allocation of capital between the food and nonfood sectors is important, an exploration that needs to commence with the work of Sen and be pursued in the context of the now well-known potentials for technological change in agriculture. From these analyses can spring the understanding of food processes and relationships of the next few decades which are essential to policies for more efficient pursuit of people's objectives in this extraordinarily dynamic period.

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Soviet Grain and Wheat Import Demands in 1981–85

Padma Desai

Soviet imports of grain, including wheat, have become large in recent years. The U.S. Department of Agriculture (USDA) has estimated that the Soviet Union imported 35 million tons of grain in the consumption year ending 30 June 1981.[1] These imports will continue to be large in the near future because of the Soviet decision to increase the production and consumption of meat and dairy products without slaughtering livestock in years of harvest failure.

While the imports have not been large in relation to Soviet grain output, they are substantial in relation to world grain trade. If they are also variable, they could create disruption in world grain trade with serious consequences for both grain-exporting and grain-deficit countries.

It is therefore of utmost importance that future Soviet grain imports are estimated soundly. Accordingly, we predict these imports during 1981–85. In the first section, we predict grain imports as the difference between total supplies and requirements with the major components of the two categories estimated from simple regressions. We also predict wheat imports separately by using the same methodology. In the second section, we modify the methodology of forecasting grain output in one respect: we estimate grain production not from past trends, but by fitting a simple Cobb-Douglas production function with constant returns to scale to alternative sets of data. Finally, in the third section, we predict grain imports using import demand functions where the explanatory variables are domestic production of grain, meat production, livestock inventories, a time trend, and, from 1971, a dummy variable representing the policy decision to import grain to keep inventories of livestock steady.

The large weather-induced fluctuations in Soviet grain and wheat output make it necessary to forecast grain and wheat outputs and imports by defining below-average harvests associated with unfavorable weather and above-average, with favorable weather. Accordingly, we make three sets of grain and wheat output forecasts in this paper.

Among our major conclusions are the following: the Soviet Union will need to import up to 32 million tons of grain in a below-average year, and wheat imports will constitute up to 14 million tons of these. Average annual grain imports during 1981/82–1985/86 will be up to 17.9 million tons and the Soviet planners will be able to meet the foreign exchange costs of these imports.

In the following analysis, we shall estimate Soviet deficits of grain from grain data (USDA 1980, p. 29) as the difference between output, on the one hand, and the requirements, on the other, for feed grain, seed, industrial and personal consumption, dockage waste, export commitments, and additions to reserves. We also introduce variations in the weather pattern in our estimation. We then present the resulting estimates of grain deficits as estimates of Soviet grain imports between 1981/82 and 1985/86. We also derive estimates of wheat imports from a similar supply-demand exercise based on wheat data (USDA 1974, p. 31 and USDA 1980, p. 30).

Grain Import Estimates

The first step in the sequence of our estimation is the forecast of grain output. We predict

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The methodology in this paper draws heavily on an earlier report by the author on estimates of Soviet grain imports, 1980–85, published by the International Food Policy Research Institute. In this paper, the data are updated and the methodological formulations altered and improved wherever possible.

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[1] All tons in this report are metric tons. The data, unless otherwise stated, are from USDA. The years, unless otherwise noted, are grain-use or consumption years. They extend from 1 July of one year to 30 June of the next.

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grain output from equation (1) on the basis of the linear trend of past output during 1955/56 to 1978/79:

$$(1)\quad (\text{Grain output})_t = \underset{(11.2644)}{97.8177} + \underset{(7.7746)}{4.7249t},$$

where $R^2 = 0.7332$, DW = 2.81, SER = 20.6095, and $t = 1,2, \ldots, 31$. In all the equations of this paper, R^2 is the correlation coefficient, DW is the Durbin-Watson statistic, and SER is the standard error of the regression. Values in parentheses are t-values of the estimates.

Among the four possibilities of the linear or semilog trend of past output, or yield, we choose the linear trend of output because with almost indistinguishable R^2 and DW, it has the minimum estimated variance of predicted outputs.

We estimate the grain outputs with a 60% confidence interval with the lower estimates characterized as below average and the upper, as above average. The intermediate trend estimates are average outputs. This procedure is necessary because the extreme weather-induced variability of annual output (indicated by the estimated standard error of 20.6 million tons in equation [1]) renders point estimates meaningless.

Our estimates of grain imports in a below-average year or domestic stock accumulation possibilities and/or exports in an above-average year corresponding to a 60% confidence interval can be interpreted as: chances are 60% (almost two in three) that the actual imports (or additions to stocks plus exports) will not exceed the stated estimates.

Furthermore, ten of the twenty-six observations (i.e., approximately 40%) from between 1955/56 and 1980/81 are outside the limits set by the 60% confidence interval. It is clear from observing the data that of these ten observations, five (1963/64, 1965/66, 1975/76, 1979/80, and 1980/81) are outside the lower range of the interval and five (1956/57, 1958/59, 1973/74, 1976/77, and 1978/79) are outside the upper range. Two of these, 1956/57 and 1958/59, are almost on the boundary. Indeed, a further investigation of the distribution of the output observations indicates that, whereas the above-average observations are close to the upper boundary of the 60% range (with two out of five almost on the boundary), the below-average observations are far from the lower boundary of the 60% confidence interval.

This pattern reveals the asymmetric impact of extremes of weather on output. It implies that if we select a wider confidence interval, such as 70%, we might overstate output if the weather is better than average. On the other hand, in settling for the 60% confidence interval, we might overstate output if the weather is worse than average.

In order to counteract the latter possibility, we estimate the average size of the net output shortfall that can be attributed to the weather asymmetry. Thus, the actual surplus of the five above-average years is estimated by subtracting from the actual output the corresponding output of the upper 60% range; similarly, the actual shortfall of the five below-average years is estimated by subtracting actual output from the corresponding output of the lower 60% range. The net deficit of 67.9 million tons is the difference between these two totals; when we distribute it over the five below-average years, our estimate of average output shortfall due to asymmetric impact of weather in a below-average year turns out to be 13.6 million tons. Therefore, we subtract 13.6 million tons from the output estimate of the lower range of the 60% confidence interval in a below-average year.

How do the estimated outputs in table 1 compare with actual Soviet performance during the Tenth Five-Year Plan from 1976 to 1980 and targets of the Eleventh Plan ending in 1985? (As far as the amount of grain produced is concerned, the calendar year and the USDA consumption year [July 1 to June 30] are interchangeable.) First, the below-average and above-average grain output estimates suggest that with a 60% confidence interval, Soviet grain output can vary as much as 48.6 million tons (that is, 35 plus 13.6 for weather asymmetry) in a given year. Second, actual average output between 1976 and 1980 was 205.1 million tons. Allowing for actual weather during 1976–80 and subtracting 13.6 million tons from the output of each of the two below-average years of 1979 and 1980 to allow for the asymmetrical input of bad weather, we get an estimate of the annual output during the Tenth Five-Year Plan of 205.7 million tons, close to the actual output of 205.1 million tons. Finally, the estimated average output during 1981/82–1985/86 is 234.8 million tons. This indicates that the Soviets will fall short of their Eleventh Five-Year Plan target of 238–43 million tons by 3–8 million tons. Undoubtedly the Soviet planners will revise their target.

In conclusion, we must emphasize that we will estimate grain imports in 1981/82 by employing both our predicted output of 194.1 million tons (207.7 minus 13.6 for weather asymmetry) and the USDA estimate of 175.0 million tons.

Estimating Feed Grain Requirements

Our prediction of feed grain requirements from past patterns must take account of the Soviet decision to increase consumption of meat and dairy products without livestock slaughter when harvests fail. The implementation of this policy becomes evident in 1971 when the Soviet planners began substantial imports of grain to make up, although partially, the shortfall in domestic production.

Accordingly, we use equation (2) to predict feed grain use. In this equation, we regress feed grain use between 1955/56 and 1980/81 on time and a simple dummy variable of 1 beginning from 1971:

$$(2)\quad \underset{(7.1016)}{-177.0429} + \underset{(1.9537)}{11.9731}\,(\text{dummy}) + \underset{(9.1480)}{3.4367t},$$

where $R^2 = 0.9465$, DW $= 1.1577$, SER $= 7.9571$, and $t = 55, 56, \ldots, 85$.

We present the feed grain estimates of equation (2) from 1981/82 to 1985/86 in table 1. These suggest that the use of feed grain will increase during the period, reaching a level of 144 million tons in 1985/86. Taking account of the disastrous 1981 harvest, we shall employ an estimate of feed grain use of 125 million tons in 1981/82 instead of 129.5 million tons resulting from equation (2).

Estimating Seed Requirements

We use equation (3) for extrapolating seed use. It is estimated from seed use data from 1955/56 to 1980/81:

$$(3)\quad (\text{seed use})_t = \underset{(3.8629)}{-7.5077} + \underset{(16.2715)}{0.4656t},$$

where $R^2 = 0.9169$, DW $= 1.0450$, and SER $= 1.4937$, and $t = 55, 56, \ldots, 85$.

The estimates of seed requirements based on this equation, presented in table 1, increase steadily through 1985/86.

Table 1. Estimated output and Use of Grain, 1976/77–1985/86 and Grain Imports, 1981/82–1985/86

	Output			Use					Dockage Waste			Imports		
Year	Average	Below Average	Above Average	Feed	Seed	Industrial and Human Consumption	Export Commitment	Addition to Stock	Average	Below Average	Above Average	Average	Below Average	Above Average
							(million metric tons)							
1976/77			219.4											
1977/78	206.5													
1978/79			228.9											
1979/80		198.3												
1980/81		203.0												
1981/82	225.4	207.7	243.1	129.5	30.2	50.0	1.0	5.0	22.5	10.4	30.4	13.8	19.4	4.0
		(175.0)		(125.0)						(8.8)			(45.0)	
1982/83	230.1	212.4	247.8	133.1	30.7	50.0	2.0	5.0	23.0	10.6	31.0	13.7	19.0	4.0
1983/84	234.8	217.2	252.5	136.8	31.1	50.0	2.0	5.0	23.5	10.9	31.6	13.6	18.6	4.0
1984/85	239.6	221.9	257.2	140.4	31.6	50.0	2.0	5.0	24.0	11.1	32.2	13.4	18.2	4.0
1985/86	244.3	226.6	262.0	144.0	32.1	50.0	2.0	5.0	24.4	11.3	32.8	13.2	17.8	3.9
Annual average imports between 1982/83 and 1985/86												13.5	18.4	4.0

Estimates of Industrial and Personal Grain Consumption and the Waste Dockage Discount

We assume that industrial and personal grain uses will remain stable at 4 million tons for industry and 46 million tons for people, a total of 50 million tons.

We also assume the discount for dockage waste to be 5% for below-average, 10% for average, and 12.5% for above-average production. The USDA discounts production 15% when too much precipitation causes abnormal amounts of moisture, weeds, and seeds to appear in harvested grain in an above-average year. However, our adoption of the narrower 60% confidence interval rules out the occurrence of such abnormally moist weather.

Predicting Exports between 1981/82 and 1985/86

Soviet exports of grain, mostly wheat, have declined from plan to plan in the past. We assume that exports between 1982/83 and 1985/86 will consist of wheat and rice and will average the recent level of 2 million tons, with the actual amount and its breakdown determined by the specific circumstances of a given year. For 1981/82, we assume that the Soviet Union, dealing as it is with three successive harvest failures, will decide to export no more than 1 million tons of rice and wheat.

Estimating Changes in Grain Reserves

The shortfall between domestic output of grain and requirements for feed, seed, industrial and human consumption, dockage waste, and exports can be met by reducing stocks or by importing grain. However, official information on the current size of grain reserves as of 1 July 1981 is not available. Measures taken to combat the decline in grain output in 1979 and 1980 help us resolve this issue.

Premature slaughter of livestock and decline in meat and milk outputs indicate a strenuous feed grain situation, despite massive imports of 31 and 35 million tons of grain, in 1979/80 and 1980/81. Availability of grain reserves for meeting grain shortages beginning from 1 July 1981, therefore, seems doubtful. We further assume that the Soviet planners will decide to avoid a recurrence of the recent scramble for grain imports, the involuntary slaughter of some livestock, and a further decline in meat output by adding to grain reserves at the rate of 5 million tons each year during the five years beginning 1 July 1981.

Predicting Future Weather and Output

Predicting the impact and occurrence of future weather with a precise sequence of average, below-average and above-average years is impossible. We, therefore, merely resolve the issue of their occurrence by observing their frequency between 1955 and 1980 in terms of the 60% confidence interval. As we have already indicated, a 60% confidence interval leaves five years clearly outside the lower range (below average) and five years outside the upper range of the interval (above average). The remaining sixteen observations, that is, approximately 60% fall in the average range.

We therefore assume that the weather between 1981 and 1985 will be average, below-average, and above-average in the same proportion. That is, three years will be average, one year will be above-average, and one year will be below-average. We adopt this shaky procedure because we are unable to find a firmer one. We also cannot predict the sequence of these years.

Finally, since 1981/82 has already been a below-average year, we have three average and one above-average years for the remaining period up to 1985/86.

Estimates of Grain Imports between 1981/82 and 1985/86

All the components of availability and use as estimated above are stated in table 1. We emphasize that, for 1981/82, we also work with the USDA estimate of output at 175.0 million tons (our forecast is 207.7 for below-average weather minus 13.6 million tons for the impact of weather asymmetry, that is, 194.1 million tons); the corresponding dockage waste discount is 8.8 million tons; we assume feed use of grain at 125.0 million tons (instead of the predicted 129.5 million tons) because of some depletion of livestock; finally, exports are assumed at 1 million tons (instead of 2 million tons annually during the remaining period) and addition to stocks at 5 million tons. All the estimates between 1982/83 and 1985/86 are our forecasts.

Three conclusions emerge from our exercise: first, the Soviet Union will require grain imports of 45 million tons during 1981/82. Second, imports can be 13.5 million tons in an average year; even in an above-average year, it would be necessary to import grain of up to 4 million tons; but most significantly, imports in a below-average year can be as massive as 32.0 million tons; that is, 18.4 million tons plus 13.6 million tons to allow for the asymmetric impact of weather. Finally, our estimates indicate average annual imports between 1981/82 and 1985/86 of up to 17.9 million tons.

Estimates of Wheat Imports

We predict wheat output on the basis of the linear trend of past output between 1955/56 to 1980/81. The forecasting equation is as follows:

$$(4)\quad (\text{wheat output})_t = \underset{(10.7784)}{56.6902} + \underset{(5.2430)}{1.7831t},$$

where $R^2 = 0.5339$, DW = 2.3722, SER = 13.006, and $t = 1, 2, \ldots, 31$.

We estimate wheat outputs with a 70% confidence interval, again with the lower estimates characterized as below-average and the upper, as above-average. The intermediate trend estimates are average outputs. As before, this procedure is necessary because the weather-induced variability of annual output, indicated by the estimated standard error of 13.0 million tons in equation (4), renders point estimates meaningless.

We have selected the 70% confidence interval because it is clear from observing the wheat output data that it leaves seven (that is, approximately, 27%) of the observations between 1955/56 and 1980/81 outside the interval. (If we select the narrower interval of 60%, the number of observations outside the interval increases only slightly, to 8.) Of these, three (1963/64, 1965/66, and 1975/76) are outside the lower range, and four (1966/67, 1970/71, 1973/74, and 1978/79) are outside the upper range. Moreover, we do not observe the asymmetry in the location of the below- and above-average observations. All three below-average and the three above-average observations (with the fourth for 1970/71 almost on the boundary) are located at roughly the same distance from the interval boundaries.

We state the output estimates in table 2. Actual wheat output during 1976–80, when averaged over the five years, was 99.6 million tons. Our corresponding estimated output

Table 2. Estimated Output and Use of Wheat, 1976/77–1985/86 and Wheat Imports, 1981/82–1985/86

	Output			Use					Dockage Waste			Imports		
Year	Average	Below Average	Above Average	Feed	Seed	Industrial and Human Consumption	Export Commitment	Addition to Stock	Average	Below Average	Above Average	Average	Below Average	Above Average
						(million metric tons)								
1976/77	95.8													
1977/78	97.6													
1978/79			113.2											
1979/80	87.4													
1980/81	103.0													
1981/82	104.8	91.0	118.5	46.0	15.0	37.0	0.5	5.0	10.5	4.6	14.8	9.2	17.1	−0.2
1982/83	106.5	92.8	120.3	46.0	15.0	37.0	1.5	2.0	10.7	4.6	15.0	5.7	13.3	−3.8
1983/84	108.3	94.6	122.1	48.0	15.0	38.0	1.5	2.0	10.8	4.7	15.3	7.0	14.6	−2.3
1984/85	110.1	96.3	123.9	48.0	16.0	38.0	1.5	2.0	11.0	4.8	15.5	6.4	14.0	−2.9
1985/86	111.9	98.1	125.6	47.0	16.0	38.0	1.5	2.0	11.2	4.9	15.7	3.8	11.3	−5.4
Annual average import												6.4	14.1	−2.9

with suitable allowance for weather is 99.4 million tons.

Estimating Wheat Use for Feed, Seed, Human and Industrial Consumption, and Dockage Waste

It is difficult to predict use of wheat for livestock feed. The current practice is to use imported high-grade milling wheat for producing bread and divert domestic low-grade wheat for livestock feed. With rising domestic production of high-grade wheat, the Soviet planners would find it more efficient to curtail imports of wheat and, instead, import increasing amounts of coarse feed grain, which is cheaper and provides more calories per unit of intake.

We therefore proceed to estimate wheat use for feed by assuming some substitution within feed grain in favor of coarse grain. That is, with feed grain use rising, we assume the use of wheat for livestock feed to be almost constant. Accordingly, we use the estimates of feed use of wheat for 1981/82–1985/86 of the East Europe USSR Branch of the USDA from Malish (1981). These are stated in table 2. We also use the projections for seed use and industrial and human consumption of wheat for 1981/82–1985/86 cited in Malish.

We assume dockage waste for wheat at 10% of average output, 5% of below-average output and 12.5% of above-average output.

Predicting Exports and Changes in Wheat Reserves between 1981/82 and 1985/86

We assume that the Soviet Union will export 1.0 million tons of wheat and rice in 1981/82 and 2.0 million tons thereafter, with exports of rice at 0.5 million tons annually. Furthermore, the decision (assumed by us) to add to grain reserves at the rate of 5.0 million tons annually will result in the addition of 5.0 million tons of wheat in 1981/82 (Malish) and thereafter, of 2.0 million tons of wheat and 3.0 million tons of coarse grain. Our numbers are not based on firm indications of Soviet grain reserve policies and are somewhat speculative. The relevant consideration is that the Soviet Union has long-term agreements for wheat imports of at least 7.0 million tons; therefore, *ceteris paribus*, the pressure to add to wheat reserves is less except in 1981/82 as the first priority. On the other hand, coarse feed grain, especially corn, is more difficult to procure in world markets and also more urgently needed. This should be a relevant consideration in the Soviet planners' decision to add to reserves of coarse feed grain as well.

Estimates of Wheat Imports between 1981/82 and 1985/86

All the components of availability and use of wheat are stated in table 2. Two conclusions emerge from observing the data: first, in average and below-average years, our estimated wheat imports of 6.4 and up to 14.1 million tons will be a little less than half of grain imports of 13.5 and up to 32.0 million tons. Second, in above-average years, the Soviet Union might export wheat of up to 4.2 million tons (this includes the commitment to export 0.5 million tons of wheat in 1981/82 and 1.5 million tons annually thereafter).

The Problems and Possibilities of Estimating Soviet Grain Output Using the Results of Production Functions

In the preceding section, we predicted Soviet grain production using past trends. In this section, we explore the possibility of predicting it using production function estimates.

Specification and Estimation of the Production Function

We define the agricultural production function as

$$(5) \qquad Q_t = Ae^{\lambda t}K_t^{\alpha_1}M_t^{\alpha_2}R_t^{\alpha_3}L_t^{\alpha_4}e^{\mu_t},$$

where $A > 0$, $0 \leq \alpha_i \leq 1$, and $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$.

The dependent variable Q stands for agricultural output. We represent it with Western gross and net measures, both in 1968 rubles (from Whitehouse and Havelka 1973, Carey 1976 and Carey and Havelka 1979). The former includes inputs from agriculture, such as feed grains, going into animal husbandry, whereas the net measure subtracts them. Both measures are net of trash, moisture content, and waste in storage and transportation.

The explanatory variables in equation (5) are capital stock (K) in agriculture from Soviet sources, labor employed (M) in agriculture as estimated by Rapawy (1980), current inputs (R) in agriculture as estimated by Diamond

(1966, Diamond and Krueger 1973), and area sown (L) during the agricultural year as given in Soviet sources.

In addition to capital stock, labor in man-hours, current inputs, and sown area, we include dummy variables for weather, with each year in the period classified as average, above-average, and below-average on the basis of the number of grain-growing regions that can be classified in that year as deserts and steppes. These classifications for the twenty-seven grain-growing regions of the USSR are made in a recent report of the Central Intelligence Agency (CIA 1976) for the sixteen-year period 1960–75 on the basis of the Koppen method of weather classification. On the basis of this information, we classify five years (1969, 1970, 1971, 1973, and 1974) with less than three steppe and desert regions as above-average (one year had none), and four years (1960, 1962, 1963, and 1975) with more than eleven steppe and desert regions as below average (one year had sixteen). Furthermore, we classify 1976 and 1978 as above average on the basis of the weather information available from the annual reports of the USDA on agricultural situation in the USSR. Both these sets of years are then assigned dummy variables of 1. The remaining years (including the entire pre-1960 period) are assigned values of 0.

Some preliminary results of estimating equation (5) indicate that it is not possible to estimate the coefficients of capital and current inputs because both the series grow over time and are highly collinear. We therefore merge capital, with an 8% return, with the current input series. We then discover that the estimates of the technical change and the input coefficient are strongly collinear for capital plus current inputs. We then redefine the production function as in equation (6) below and estimate it without a technical change parameter:

$$Q_t = B\, C_t^{\beta_1} M_t^{\beta_2} L_t^{\beta_3} e^{\mu_t}, \tag{6}$$

where $B > 0$, $0 \leq \beta_i \leq 1$, $\beta_1 + \beta_2 + \beta_3 = 1$, and C_t represents capital stock with an 8% annual flow plus current inputs. The other variables are defined as before. The results are in table 3.

One striking feature of the estimates is the asymmetric impact of weather on output indicating a decline in output, caused by below-average weather twice as large as the gain in output resulting from above-average weather.

Predicting Future Output of Grain and Inputs in Agriculture and Weather during 1981–85

Taking past and recent growth patterns into account, we assume that agricultural capital stock will grow 7% and current inputs, 5% each year; that man-hour application will decline 0.5% annually; and that the amount of cultivated land in agriculture will remain fixed at 218 million hectares. We shall assume as before that the years 1981 to 1985 will have three average years, one above-average year, one below-average year. We will ignore the sequence of their occurrence. Because our estimated production function parameters already account for the asymmetry of weather's effects on output, we will not allow for the asymmetry separately in these forecasts.

Table 3. Production Function Estimates for Agriculture, 1950/78

	Coefficients							
Measures	Capital and Current Inputs β_1	Labor β_2	Land β_3	Above-Average Weather	Below-Average Weather	ln$B$	R^2	DW
Western gross output	0.3870 (9.0270)	0.1573	0.4557 (2.6409)	0.0301 (1.1325)	−0.0785 (2.6699)	0.2479 (0.9565)	0.9793	1.5433
Western net output	0.3360 (7.4982)	0.0685	0.5954 (3.3009)	0.0314 (1.1297)	−0.0853 (2.7756)	−0.1137 (0.4197)	0.9754	1.6611

Converting Predicted Agricultural Output into Tons of Grain Output

We use the estimates in table 3 derived from Western gross output for our forecasts of grain imports. To convert the predicted ruble values of these outputs into the comparable Soviet tonnage measure, we first assume that the ratio of the 1968 ruble measure and the underlying Western tonnage estimate for 1981–85 remains the same as for the period 1960–75. We multiply the ruble estimate by this estimated ratio, 1.3209, to get the corresponding tonnage estimate. We then divide the latter by 0.6302, producing the comparable official Soviet measure of grain output, because the official Soviet figures for grain tonnage must be discounted by 0.6302 to get the Western grain tonnage figures.

The resulting estimates of grain output and the corresponding imports are stated in table 4. First, for the period between 1976/77 and 1980/81 of the Tenth Five-Year Plan, grain output averages 204.8 million tons. The actual output was 205.1 million tons. Second, our estimated weather parameters do indicate the asymmetric impact of below-average weather. Finally, with grain use in various categories defined as before, we note that grain imports in average years average at 14.3 million tons, in below-average years at 19.3 million tons, and in above-average years at 13.8 million tons. The corresponding import figures from the trend methodology are 13.5, 32.0, and 4.0 million tons. It would seem that the import values for below and above-average years from our production function estimates could perhaps be made more realistic by adopting more appropriate weather variables.

Estimates of Grain Imports from Regression Estimates of Import Demand Function

We make the final set of estimates of grain imports for 1981/82–1985/86 by fitting Soviet import data for grain directly to several explanatory variables.

The explanatory variables are output of grain (Q_G), price in dollars per metric ton of imported grain (P_G), production of meat (Q_M) and number of livestock (Q_L). We estimated the regressions, both linear and log-linear, for the period 1950–79. All the data are from Soviet sources and are for calendar years. Among the explanatory variables, we lag domestic grain output (Q_G) and price per ton of imported grain (P_G) by one year to account for the lag between the decision to import grain and its delivery. The dependent variable, grain imports (I_G) is specified on a gross basis. Finally, we introduce a dummy of 1 from 1971 to reflect the shift in policy mentioned above.

Characteristics of the Actual Import Pattern

We must interpret the estimated parameters in terms of the analytical framework suggested by the actual Soviet import pattern during the period, including the change in policy that became evident in 1971. We proceed on the basis

Table 4. Estimates of Grain Output Based on Production Function Parameters for Agriculture, 1976/77–1985/86 and Imports, 1981/82–1985/86

				Dockage Waste			Imports		
Year	Average Output	Below Average Output	Above Average Output	Average	Below Average	Above Average	Average	Below Average	Above Average
	(Million Tons)								
1976/77			204.697						
1977/78	203.615								
1978/79			215.732						
1979/80		197.756							
1980/81		202.174							
1981/82	223.593	206.714 (175.0)	230.425	23.6	10.3 (8.8)	28.8	15.7	19.3 (45.0)	14.1
1982/83	228.589	211.331	235.576	22.9	10.6	29.4	15.1	20.1	14.6
1983/84	233.697	216.054	240.839	23.7	10.8	30.1	14.9	19.6	14.2
1984/85	238.969	220.927	246.269	23.9	11.0	30.8	13.9	19.1	13.5
1985/86	244.334	225.885	251.799	24.4	11.3	31.5	13.2	18.5	12.8
Annual average imports between 1982/83 and 1985/86							14.3	19.3	13.8

of the following characteristics of grain imports during the period.

First, the Soviets do not use imports to make up the entire shortfall of domestic production. Rather, a shortfall is usually accompanied by other measures, such as rationing of bread, slaughtering of livestock and reduction of stocks. Therefore, we reject values of the estimated coefficients of imports (I_G) in relation to domestic production (Q_G) that are greater than 1 in the linear relationship. The signs of the estimated parameters should, however, be negative. Second, while it is reasonable to assume that the Soviet planners do not make up the entire shortfall in domestic production with imports, the amount of grain imported will be influenced by the amount of grain produced domestically. Therefore, we will use the below-average and above-average outputs generated by the 60% confidence interval to estimate the corresponding amounts of grain imports. Third, we must speculate also on the response of imports to prices of grain (P_G) lagged by one year. One would assume that the price elasticity response is low, perhaps less than 1 in the log-linear relationship because Soviet import decisions in the past were influenced by considerations other than price. From 1971, the important consideration is to maintain livestock inventories as it will continue to be in the future. Therefore, price will not have a decisive effect on imports. In any case, the signs of the estimated coefficients should be negative. Finally, we need to discuss the implications for grain imports of Soviet meat production (M_G) and livestock inventories (Q_L). These are straightforward because rising meat production and livestock inventories would, other things being equal, require feed grain inputs, including those from imports, to increase, so that the sign of the estimated parameter will be positive.

Estimation Procedure and Criteria of Selecting the Preferred Regression

Preliminary results indicated high collinearity between meat production (Q_M) and time (t) and between livestock inventories (Q_L) and time (t). Also, meat production (Q_M) and livestock (Q_L) are economically more meaningful variables, but time (t) is easier to forecast. We therefore present and use all three equations below, each with meat production (Q_M), livestock inventories (Q_L) and time (t) for our calculations because they cannot be distinguished on the basis of the statistical criteria. Second, the estimated parameter with regard to price of imported grain (P_G) is always statistically nonsignificant. Furthermore R^2 improves when we omit it from consideration. Finally, when we attempted improving the DW statistic with first-order serial correlation correction, R^2 dropped significantly in all cases.

We present below the regression estimates from the linear trend of imports (I_G) between 1950 and 1979 on $(Q_G)_{t-1}$, (Q_M), (Q_L), time (t), and dummy variable 0 (up to 1970) and 1 (after 1971) which were statistically most satisfactory:

$$
\begin{aligned}
(7)\quad (I_G)_t = {} & \underset{(2.0905)}{7.3000} - \underset{(2.9086)}{0.1165}(Q_G)_{t-1} \\
& + \underset{(3.7924)}{0.8831}(t) + \underset{(3.8676)}{10.20865}\ (\text{dummy}),
\end{aligned}
$$

where $R^2 = 0.7985$, SER $= 3.9320$, DW $= 1.3570$;

$$
\begin{aligned}
(8)\quad (I_G)_t = {} & \underset{(0.3831)}{-1.4522} - \underset{(2.2160)}{0.1171}(Q_G)_{t-1} \\
& + \underset{(2.6567)}{2.0879}(Q_M)_t + \underset{(3.7144)}{11.0431},
\end{aligned}
$$

where $R^2 = 0.7525$, SER $= 4.3581$, DW $= 1.3061$; and

$$
\begin{aligned}
(9)\quad (I_G)_t = {} & \underset{(2.6808)}{-24.4093} - \underset{(2.4385)}{0.1075}(Q_G)_{t-1} \\
& + \underset{(3.1341)}{0.3683}(Q_L)_t + \underset{(4.0281)}{11.1096}\ (\text{dummy}),
\end{aligned}
$$

where $R^2 = 0.7721$, SER $= 4.1815$, DW $= 1.4644$; $t = 1, 2, \ldots, 35$ in all the equations.

The equations suggest an extremely stable and interesting pattern of the effects of the explanatory variables on Soviet grain import behavior. The coefficients of 0.11–0.12 for domestic grain output imply that only 0.11 to 0.12 million tons of grain are imported to offset a million ton decline of grain output. Also, the decision to increase meat and dairy products output from 1971 without slaughtering livestock will add 10 to 11 million tons to grain imports each year.

Estimates of Grain Imports

We employ equations (7), (8), and (9) for estimating grain imports for 1981–85 for below-average weather only. These are shown in table 5. We assume that below-average grain

Table 5. Estimated Grain Imports in Below-Average Years from Import Demand Equations, 1981–85

Year	Equation (7)	Equation (8)	Equation (9)	Meat Output	Rate of Growth	Livestock Numbers	Rate of Growth
	(Million Tons)				(%)	(Million)	(%)
1980				15.1			
1981	32.9	28.8	31.1	15.3	1.5	148.8	
1982	36.1	31.7	33.7	15.6	2.0	150.3	1.0
1983	33.7	29.5	33.6	16.1	3.0	152.6	1.5
1984	34.1	30.4	32.0	16.7	4.0	154.9	1.5
1985	34.5	31.5	32.8	17.4	5.0	158.0	2.0
Average annual imports	34.3	30.4	32.6				

output for 1981–85 will be the same as given in table 1; the rates at which we have predicted future meat output will rise from the actual level of 15.1 million tons in 1980 to the targeted level of 17.4 million tons in 1985; similarly, starting with a depressed level of 148.8 million head in 1981, livestock inventories are also assumed to build up gradually. Finally, the estimates resulting from the equations refer to Soviet import data for calendar years; they are adjusted upward by 23% to bring them in line with USDA import data of the preceding sections which are for a consumption year lasting from 1 July to 30 June. Finally, we add 5.0 million tons each year to allow for our assumed requirements that grain reserves be augmented annually by that amount.

Our resulting average annual import estimates ranging from 30.4 to 34.3 million tons from the three equations are remarkably steady; the estimates are also close to the import estimate of up to 32.0 million tons for a below-average year from the trend methodology.

The Hard Currency Costs of Grain Imports

Our estimates from the trend methodology of the first section indicate average annual imports between 1981/82 and 1985/86 of up to 17.9 million tons. Furthermore, they also indicate imports of up to 32.0 million tons in a below-average year. The latter figure is further supported by all the estimates from the import demand equations.

According to information in a World Bank report, the price of grain per ton is expected to rise from $165 in 1979 to $274 in 1985. An average price of $220 per ton would give an annual import bill, for financing up to 18 million tons of grain, of about $4.0 billion annually.

Can the Soviet planners afford to spend the hard currency? If we assume Soviet hard currency export earnings to increase annually at the rate of 15% in 1979 and 1980, and if this rate slows 1% annually to 10% in 1985, then the annual grain import cost of $4.0 billion will be 20% of the projected hard currency merchandise earnings in 1981, and 13% of these earnings in 1985. We can expect the amortization of debt to increase from about 27% of these earnings in 1981 to 31% in 1985, leaving the Soviet Union with 53%–56% of its hard currency export trade for machinery imports from the West. Considering that the hard currency earnings do not include receipts from sales of arms and nonmonetary gold or from transport and tourism, the grain import bill estimated by us seems to be manageable.

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China As a Factor in the World Food Situation

Anthony M. Tang

To see China as a factor in the world food situation it is necessary to examine worldwide trends first. Ever since Malthus's dismal prediction, alarmists have periodically foretold approaching disaster, only to be followed by alternating waves of optimism accompanied by surges in food production. Globally, the historical trends have been reassuring about man's ability to keep food output growth ahead of population growth. The race has been won despite the fact that since the end of the eighteenth century the world has witnessed an unprecedented population explosion, with mankind multiplying himself by about four and a half times. The burgeoning numbers have been attributable mainly to exogenous improvement in medicine and health measures rather than to the workings of the forces responsible for the so-called "demographic transition" in economic development. The future appears more reassuring in this regard as the developing nations appear finally to have entered the transition phase and begun to show noticeable declines in fertility (Wortman and Cummings, p. 29). Falling fertility rates are expected to continue among the developing nations, with total world population reaching perhaps 6 billion by the year 2000 instead of the much higher earlier forecasts, possibly stabilizing itself as early as 2020. This hardly suggests, however, that the increase in the number of mouths to be fed will not be substantial in the period ahead. World population will have risen by more than 70 million in 1981 alone, and by the year 2000 the annual increase may be half again as large as at present.

What are the prospects for food production, in particular grain output? The historical record and thoughtful assessment of the key factors at work probably warrant cautious optimism. World grain output has kept ahead of multiplying numbers. Per capita consumption has risen strongly in the high income countries and at least marginally in the less developed world. U.S. Department of Agriculture (USDA) world crop production statistics puts total world grain output (wheat, coarse grains, milled rice) at an annual average of 851 million tons in the early 1960s. By 1980/81, roughly two decades later, it has reached 1.44 billion tons, a rise of nearly 70%, or an average rate of nearly 3% a year. The average leaves a margin of 1% a year as per capita improvement. These averages mask the fact that in the 1970s aggregate performance showed some weakening. The commodity crunch of 1972–74, coming on top of unusually strong global economic growth, decimated the U.S. food stockpiles and its set-aside acreages. The margins have been built up, however. According to USDA estimates, the world entered the 1980s with about the same stocks-to-consumption ratio in grains as a decade ago, about 16%, or a 60-day supply. Concern centers on the uncertain Soviet grain output and the distribution of cost and responsibility of the world's reserves. U.S. government agencies (USDA and CIA) tend to project an extension of past margins with output overshadowing population in growth, while stressing the technical possibilities for the predicted outcome. Despite lack of consensus, it is probably prudent to share Barnett's considered judgment for the balance of the century that the outlook "does not justify apocalyptic predictions of disaster" (p. 279).

There are several points on which there is general awareness and some agreement. (*a*) Though technically plausible, the worth of the relatively sanguine forecasts hinges on responsible and effective government policies in economic and demographic domains. It is well to note, however, some new technological directions of possibly great future import. The new plant and animal genetics opens up a

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boundless horizon beyond the once-exciting Mendelian confines of cross-breeding. No-tillage farming offers a possible solution to an old, but once again threatening, problem of massive soil erosion (wind-borne or otherwise), as well as prospects of growing field crops on slope land. (*b*) Even if the global balance continues to hold with a positive edge for further diet improvement, enormous problems of distribution remain. These problems, indeed, are almost certain to grow, with the United States continuing to expand its role as the major supplier of food in the world market and the low income countries increasing their dependence on food imports. Actually, food production has been increasing at a slightly faster rate in the developing world—at 3% between 1954 and 1973—than in the developed countries—at about 2.7%. The former's deficits were attributable primarily to its higher population growth and income elasticity of demand for food. One estimate places the developing world's (excluding China in the context of all these discussions) dependence by 1985 at two to three times the 1970 level of 23.5 million tons, matched by a comparable current surplus from the developed countries (Schertz, p. 30, and Barnett, p. 281). Such increasing dependence is expected to obtain despite the fact that high income, large, grain-producing countries consume enormous (and increasing) per capita quantities of grain via indirect forms of consumption. More grain is consumed by livestock in the United States and the Soviet Union than by all the people in the developing world—which includes about half the world population, with China excluded (Brown and Shue, p. 2). Hunger is not a technical necessity, it is an economic phenomenon. As Charles Shuman puts it, "there are no hungry people where there is money to buy food" (Brown and Shue, p. 2).

Perhaps less familiar to us are three other related points. (*a*) Rising livestock numbers provide added scope for adjustment of food supplies in response to output fluctuations. This is illustrated by the dramatic 1974–75 reduction in livestock feeding in the United States, which took place when grain supply shortfalls drove up feed prices relative to livestock product prices, thus increasing grain availability for nonfeed use both here and abroad. The latter use represents an effective way of stretching short supplies, an adjustment that is both automatic and relatively painless. (*b*) The cushion provided by livestock in the high income countries served to dampen world market price shocks which would have been all the sharper because of the inability (some say unwillingness) of the low income countries to allow price to function as a rationing device and reduce the already nutritionally vulnerable level of grain consumption of their poorest people. According to figures cited by Mellor, for the lowest income countries a 10% decline in grain supply may lower by as much as one-third the real incomes and grain consumption of their poorest people, while the top 5% income receivers may experience only an 8% drop in real income and virtually no reduction in grain consumption (IFPRI, p. 2).

China as a Historical Factor

World food studies have tended to pay little attention to China under the implicit assumption that the country, however large, has been essentially self-contained in food balance terms and likely will remain that way. For a society closed until just recently, little understood and analyzed except by a small corps of frustrated China watchers, that tendency was perhaps natural. In this connection, Barnett's recent definitive study of the Chinese economy in global perspective, a major part of which is devoted to food, cannot be more timely or helpful. The purpose of this paper, thus, is to complement Barnett's tour de force by focusing on certain aspects not stressed by him and by doing some updating. In doing so we shall take up (*a*) the internal workings of Chinese agriculture within the context fashioned by the Chinese Communist Party (CCP) and its economic design, (*b*) the implications of current reforms and the ongoing readjustment, and (*c*) an assessment of future prospects in light of the historical record and current changes.

Some Comparative and Perspective Statistics

China is by a considerable margin the largest nation in the world. It produced in 1980/81, according to USDA statistics, 275.9 million tons of grains (wheat, coarse grains, rough rice), or 17.7% of the world total. It feeds some 23% of the world's population. It is the dominant rice producer, accounting for 35.2%

of the world total in 1980/81. Its shares in wheat and coarse grain output are, respectively, 12.4% and 11.4%. It ranks third in fertilizer production while remaining in recent years the world's largest importer (absorbing a staggering peak total of 2.2 million tons in nutrient weight in 1978) of chemical fertilizers. Beginning with its role of a relatively minor net food exporter in the 1950s, by the late 1960s it ranked between the tenth and the twentieth in total value of agricultural trade. In 1980/81 its wheat imports (13.8 million tons, up sharply from 8–9 million tons during the three preceding years) were second only to Russia's, accounting for 14.8% of total world imports. Chinese rice exports have averaged around 10% of the world total in the late 1970s, but recent drops brought its share to a low of just under 5% in calendar 1981. These statistics make it plain that China looms large in global food situations, that the country's role in world food trade has been increasing, and that fairly small relative changes in its food balance, either as short-run manifestations or as long-term trend tendencies, translate into large absolute magnitudes with serious impact on the global picture. In the following historical section we shall draw on our earlier studies for a summary of the workings of the forces responsible for the secular and short-run disequilibria in Chinese food balance.

The Chinese Historical Record—Trend

Because of the value-goal imperatives of the CCP, the development strategy of the People's Republic of China centers on the modern heavy industrial sector whose absolute size determines national power. It requires a command economic system for implementation because of the underlying need for mobilizing resources. The uncommon sense of urgency and the maximum-speed growth philosophy symbolically turn bread into an intermediate good and steel becomes the final good. Agriculture plays a supportive role, supplying industry with the wage good, labor, raw materials, and exportables. Its contribution to the growth process lies not so much with its output as with the "agricultural surplus" which the state siphons off. Owing to China's unfavorable initial condition, agriculture became the binding constraint on industrialization (Tang 1968). Operationally, it became necessary for the planner to apply maximum squeeze on agriculture and to attempt to develop the sector at the same time, a task fraught with difficulty. Even so, gross farm output (in constant 1952 prices) more than doubled during 1952–80, with the output index reaching 237% (1952 = 100) in 1980, a creditable record yielding an average annual compound growth rate of about 3% (as estimated from the exponential trend). Aggregate output, along with the input series, is estimated by us for the entire period (Tang 1981, Tang and Huang) and can be reconciled reasonably with the official data fragments since 1977.

The aggregate input index, however, rose even more rapidly, reaching 260% in 1980. Both total factor productivity and primary factor productivity dropped as a consequence. Value added per worker (in 1952 prices) fell by 26% from the 1958 peak of 280 yuan. More serious from the standpoint of the two-sector model, priority industry suffered serious reverses in the terms of trade that governed real resource flows between the two sectors. In exchange for a roughly constant fraction of total agricultural output (about 25%), industry's supply of inputs for agriculture has risen from less than 10% in 1952 to nearly 40% of total agricultural output, industry's supply of inputs for agriculture has risen from less than 10% in 1952 to nearly 40% of total value of agricultural output in 1980. Chinese output growth has been clearly high-cost growth. To help cover the rising cost in real terms, Peking has found it necessary to alter prices paid and received in favor of agriculture periodically. The large cumulative "scissors" price corrections, however, do not appear to have accomplished anything more than to allow agriculture to keep the large income gap in favor of the cities from getting larger.

It is difficult to work with recently released Chinese income statistics because of ambiguity in scope, definition, treatment of home consumption, and different constant price bases for different subperiods without explicit links between them. Working with our own estimates of output and inputs in constant 1952 prices, applying official price inflators to marketed output and purchased inputs, deflating the current price difference between output and inputs by the official rural (posted) retail price index, and finally adding to the latter the home-consumed output (at 70% of our estimated output), one can obtain estimates of "net" farm income in 1952 purchasing power for comparison over time. Turning to 1979, for which the latest official income fragments are available for comparison, our per worker "net" income in 1952 purchasing power, as estimated, comes to 280 yen (¥) for 1979—or ¥96 per farm person, compared with a current price estimate of about ¥130 from Chinese sources. Our estimate of ¥280 for 1979 is to be compared with ¥258 for 1958, the peak year in the relatively normal 1950s before China became fully engaged in the great radical experiment known as the Great Leap Forward. The comparison yields a paltry 8% growth over the twenty-one-year period, or just under 0.4% a year.

In passing we note that in Taiwan, although during the 1950s and much of the 1960s government squeeze on agriculture was not much less harsh (through land tax and compulsory delivery tied to the tax, both of an in-kind lump sum character, and fertilizer-rice barter) than the impositions on the mainland, real farm income (in rice terms) according to Samuel Ho's estimates more than doubled (rising by 107%) during 1948–59 for the "typical" farm household that had derived the full benefit from the 1949–53 land reform, i.e., rising from tenant farmer to owner-operator. Incomes rose for several reasons: weak disincentive structure of Taiwan's extractions, vigorous and successful government push to raise the state of the agricultural arts (both on the production-input side and the product side), competence and the high ratio of agricultural technicians, and massive transfers to cultivator households of (rising) incomes that would have gone to the landlords as rent. Ho puts the latter transfers at 85% of the estimated rise in real income of the cultivator household (p. 170). These large transfers materialized because of (*a*) the initial undervaluation by government (by about 50%) of the land compulsorily sold to the landless, (*b*) the nominal interest of 4% per year on deferred payments for the purchase price by the new owners when market interest was nearly ten times as high, and (*c*) the declining value of each successive payment against a background of rapidly rising land productivity (not associated with generally rising price levels, since the payments were denominated in kind). In contrast, land redistribution on the mainland was soon followed by collectivization, where the collective farm was more an arm of the state siphoning off rent than a cooperative capturing scale economies for its members. The urgency and character of the development strategy required holding household incomes and consumption at near-subsistence levels, permitting little improvement over time. The extraction procedures, far from being lump sum in character, became nearly confiscatory at low margins. It is against such a comparative backdrop that one can begin to fathom the broad long-term sweeps that underlie the Chinese agricultural setting—a setting characterized by rigidity and command from the center, by falling productivity, by rising costs (to industry) of output growth, and by a virtual absence of forward motion in household incomes. The backdrop is necessary to an understanding of the present movement of reform and readjustment in China.

In grain terms, China managed an output growth rate of about 2.3% a year, just ahead of population growth and below the less developed country (LDC) average of about 3%. To maintain essential food balance (and distributive equity) against a relatively healthy overall gross national product growth rate of some 5% a year, Peking permitted little "trickling down" in household incomes (urban and rural) and imposed rationing of basic commodities to deny expression to income elasticity. Peking also sought to hold population growth in check during part of the period. Near-total neglect of new housing construction, not reversed until three years ago, contributed much to this end. China's average population growth rate of 2.1% a year during 1952–80 is substantially less than the LDC average. These measures to restrain growth in demand allowed some minor improvement in Chinese diet without requiring anything more than manageable net grain imports beginning with 1961.

The Chinese Historical Record—Short-Term Fluctuations

Short-term grain supply fluctuations in China have been of two sources, weather and policy cycles. We have earlier (Tang 1980b, Tang and Huang 1980) investigated the historical content of the two sources. It turns out that strenuous Chinese efforts to control and modify nature notwithstanding, weather continues to have about the same impact on agricultural performance. Weather impact on China's total agricultural output and productivity has been minor because of its diverse climate, size, and latitudinal location. Several factors influenced the weather-productivity relationship in the past. Taken together, they tended to be self-cancelling. While Peking can make its agriculture more resistant to weather, cost and system constraints make it doubtful that the historical record will be much altered in the future. Weather will remain a relatively unimportant factor in China in sharp contrast to its role in the Soviet Union.

Policy cycle in socialist economies has been the subject of a number of investigations. Granting the existence of policy cycles, we have earlier (Tang 1980b, Tang and Huang 1980) confronted the data to see whether such cycles had exerted direct impact on agricultural production. Several tests seem to leave little doubt that policy cycles and weather had exerted separate influences on Chinese agriculture, and that the cyclical effect was subject to little or no lag (within the context of the annual data utilized). Commitment of post-Mao leaders to a steady and moderate course of policy direction should significantly reduce future cyclical inclinations.

Chinese grain purchases in the past have been unsteady, though less fluctuating and unpredictable than Soviet imports, ranging from lows of about 2 million tons a year to the current high of 15 million tons. There are reasons to believe, however, that China, under Mao in particular, had been building a national strategic reserve (Tang 1980a). It is, therefore, unclear whether China's variable purchases had served to steady the world grain market rather than destabilize it as has been true with large Soviet periodical forays, although it is also evident that Peking has not always been able to adjust its purchases according to market conditions (Barnett, p. 364). At any rate, the current U.S. practice of negotiating bilateral long-term annual purchase contracts and of requiring ad hoc negotiations for any additional quantities should serve to reduce instability in the world grain market and to allocate the cost of the vital stockpiling more in the direction of the sources of disturbance. The latter point becomes all the more weighty when supply disturbances are traceable to unwitting government policy and when governments choose (sometimes out of necessity) not to minimize the impact on the world market by refusing to allow domestic prices to rise or to otherwise reduce domestic consumption. Nor does China's reticence to join international stock management matter so long as it builds and maintains its own reserves. China's vulnerability in terms of its thin margin of production over subsistence brings the issue of food security to the forefront and makes a national stockpile of prudent size mandatory. The Soviet Union, its frequent production shortfalls notwithstanding, is not threatened by food insecurity. Even in a disastrous crop year (as is the case with 1981 with a projected harvest of 175 million tons) its grain availability per capita without imports is still more than twice that of China in a good year. Soviet domestic stockpiling behavior and attitude toward international reserve issues are accordingly different.

Reforms and China as a Future Factor

As China moves toward more decentralization in agriculture, price reform becomes crucial to the outcome. Although other reforms are being attempted, the paper focuses on price reform and certain related issues. Before turning to the task, we first take up the immediate question of whether the development strategy described earlier still holds when sweeping changes are apparently overtaking the country. The question is important because it defines the context for agriculture in the future and consequently influences the sector's performance. Space does not permit a detailed argument, already stated elsewhere (Tang 1981), that the current reforms and "readjustment" are in fact a reaffirmation of the long-held goal to be a modern, front-ranking socialist power by the year 2000. The purpose of readjustment is to correct past macroexcesses and to give priority to the bottleneck sectors (agriculture, transport, and energy) in preparation for a renewed future big-push in the modern heavy industrial sector. The latter sector, as the centerpiece of the Chinese development strategy, will continue to be the essence of the core economy, protected by centralized planning subject to "material balance" in a preemptive sense and articulated by command from the center. Current reforms are meant to flesh out the periphery (or second) economy without compromising the integrity of the core. While decentralization is the watchword for the periphery, direct allocation and quota imposition from the center will remain for the core. (For a recent authoritative statement by the vice-chairman of the CCP's Central Committee, Chen Yun, on the continued primacy of the "planned economy" and the supplementary role of the "market economy," see *Beijing Review*, 8 Feb. 1982, p. 5.)

Price Reform

The underpricing of rice (the centerpiece of the political economy of grain pricing in Asia), much lamented by T. W. Schultz, is not likely to go away. In China, where austerity in consumption is policy ordained, minimal availability of the basic staple is too central to ignore. The argument holds even when material incentive is being emphasized and consumption relaxed, as is presently the case, as means to promote productivity and economic growth. It is easy in this connection for outside observers to read too much into the ongoing policy debate in China. A number of constants are sure to remain as a matter of fact, including rationing and price control of the key wage goods. Production quotas and compulsory delivery at state procurement prices, together with state distribution of means of production, appear to be the constants for agriculture. Whether "contracting" (the preferred term currently) continues on the team level or is pushed down to the household level, as is being promoted under current reform, matters little from the standpoint of price reform. The relevant question is whether, given the larger objectives of the planner, these constraints or constants need to be there at all in a reform context. The larger objectives, which happen to be conflicting, are low price and subsistence distribution via rationing of basic food and fibers and incentive price for the producer.

Faced with this quandry, the planner remembers the economics of collective agriculture, which is to by-pass producer response to price by imposing a quota and procurement price package so as to, theoretically, extract all rent. This is the supply-side coercive equivalent to the "all-or-nothing" demand designed to take away the consumer's surplus. Let us call such supply the coercive supply. The resident cadres are, in principle, agents of the state whose task is to ensure that the collective farms under their care are not only kept on their respective coercive supply curves but made to operate at their potential output levels permitted by the allotted resources and available labor. The institution of the work point is supposed to aid their latter task by establishing the individual peasant worker's share (not necessarily its absolute worth) of the pie on the basis of his labor contribution (quality-adjusted supposedly) to total farm output. The work point system is supposed to allow a measure of work incentive while retaining the residual claimant status for the collective body of peasant "owners."

The economics of collective agriculture understood in these terms is a difficult game for the ordinary cadres to play. Even if selected from the ranks of peasants, their dual role as agents of the state and managers of the collective units entails conflicts in responsibility and interest. While individual peasants form a relatively homogenous population in terms of competence as operators of family farms, the variance of a random sample drawn from their ranks for managing large collective farms tends to be much larger. And the variance of samples drawn on the basis of ideological qualities and party membership may be even larger. It is not surprising that China analysts tend to identify diverse leadership quality as a significant factor behind China's serious income distribution problem in agriculture. The point here, however, is that the task of keeping the collective body of peasants on the state-imposed coercive supply and at a performance level up to their productive potential is probably a little daunting even for the best collective leader. At any rate, Peking's current leaders have reached the conclusion that after nearly thirty years of coercion the game is up. The conclusion brings them face to face with the pricing quandary for the necessities—a quandary sharpened by their development strategy. The quandary, to repeat, is how to increase farm prices for greater producer incentive without undermining continued rationing and low pricing of the basic food and fibers and without causing huge state budget deficits or otherwise threatening state macrotargets for investment and growth.

A paradox of the so-called development decades in the post World War II era is that the LDCs have tended to adopt "squeeze policies" toward agriculture that are antidevelopmental. Government after government has lowered, if not virtually abolished, explicit taxes on agriculture (principally, the land tax of an essentially lump sum character), replacing them with more subtle measures, such as terms of trade manipulations for domestically consumed farm products (generally through the expedient of controlling their prices while inflation goes merrily on) and export tax, or marketing board operations, or overvaluation of national currencies in foreign exchange control, or a combination of them, for export farm products. The result has been all too predictable: farmers produced less under depressed and falling prices. China, too, has been lowering its agricultural tax, although as a proportional tax on gross output its loss is not of the same order of significance. The question to ask, however, is whether China's present party leaders have the political will to impose compensatory lump sum taxes on agriculture while price reform is being put in place to encourage output.

Peking already has taken a first step in allowing optimizing behavior (at the margin) by the collective farms instead of imposing the expedient quota-price formula. While the quota remains (subject to increased procurement prices since 1979), voluntary sales above the quota are now encouraged at a 50% price premium. Although above-quota sales to the state may not be entirely voluntary, as *quid pro quos* in terms of additional amounts of chemical fertilizers often enter into the contract as inducement, it is clear that the collectives' behaviors are now closer to where the marginalist optimizers would like to be. Taking labor input as the decision-making variable controlled by the collective body, as a partial equilibrium statement a fully compensatory tax-cum-price-increase program is sure to lead to some increase in labor input and, other things being equal, to output increase. Farm household welfare is raised also. The convexity of the indifference curves and concavity of the production function (or leisure-income transformation curve) guarantee the results when full compensation is defined as imposition of a lump sum tax and simultaneous increase of product price such as to cause the new leisure-income transformation to pass through the initial equilibrium. These results are general whatever the shape of the labor supply curve in agriculture, as long as labor's marginal product is not zero. (This is also tapping a cheap source of output growth since no increase in nonlabor inputs is required.) ''Perverse'' responses may result only if the collective farms are forced into the coercive ''quota-procurement price'' point, completely off their supply curves. However, as already mentioned, the 1979 price reform encouraging above-quota sales at what appeared to be lucrative prices has probably allowed producers to move close to their respective equilibrium points on the supply curves.

With detailed production and procurement records available on each of the collective units in China, implementation of the scheme need not pose difficulties. Let us say farm prices are to be doubled in order to rationalize the price structure on the production side. Given the farm records, the farm-specific increase in revenue is calculated. This amount is also the lump sum tax to be imposed on each collective farm. Each farm is supposed to sell its entire output, and, in the case of grains, its peasant members ''buy back'' from the retail market quantities allowed them under the national rationing program at the same low prices (no increase under the scheme) paid by all other consumers. Procurement quotas are no longer necessary. (And one will want to wonder about the continued *raison d'etre* for the collective organization, cooperativization for the benefit of members in capturing scale economies being a separate matter.) ''Free markets'' (as they are known now) can be made to disappear by adjusting upward state purchase prices when needed. Price gaps between the farm gate level and retail level (assuming away marketing costs for convenience) can be maintained only if arbitrage by individuals can be prevented. Since processing is required in the case of grains and industrial crops, and since marketing and processing are state controlled, it ought not to be difficult to keep the peasants from buying low at retail and reselling high to the state. (The scheme at hand applies only to subsistence crops, grains, and to key industrial crops, such as basic fibers, also for subsistence. Vegetables and other farm products which would pose an arbitrage problem and which are nonbasic by definition, would be produced and marketed under free market conditions.) Moreover, rationing of the essentials will continue under the scheme, serving as a further barrier to arbitrage. Peasant households could withhold part of the output for home consumption to supplement official rations. But to do this they will have to overcome two problems: (*a*) the processing of grains or cotton prior to home consumption and (*b*) the high opportunity cost of home consumption of such a supplementary nature set by the high official procurement price, instead of the low retail price.

There are several other advantages to the scheme. First, the fiscal implication is minimal, since on the ''old'' production the tax and price rise are exactly offsetting. The state incurs a deficit only on the incremental output. And this burden can be passed on to the consumers without adverse effect by raising retail prices—only marginally, since the rise applies to all sales rather than the increments. Second, the lump sum tax is the least distorting of all taxes. Third, the basic idea of a relatively nondistorting tax to go along with an incentive policy measure can be extended to deal with another longstanding affliction suffered by Chinese agriculture, the well-known "scissors problem." The problem is a second focal point in recent and current Chinese price reform discussions. And it is admittedly still a serious problem despite recent corrections. To revive an old idea proposed by J. R. Hicks in 1959, let an additional lump sum tax be imposed to finance the "subsidy" (actually, removal of the "scissors" distortion) of some input or inputs whose greater use offers the further advantage of advancing productivity and the state of the art in agriculture. This is not the place to analyze the issue of input subsidy versus output price support. The input subsidy is best seen as a supplementary scheme to redress the scissors distortions on the production side without placing a new burden on an already strained fiscal state posture.

The Prospects

The compensatory tax-cum-incentive principle discussed above provides a way to reestablish rational prices needed for decentralization, which Peking seems to be encouraging outside the core economy. It will allow correct decentralized decisions regarding acquisition of Schultz's "new low-priced income streams" generated by innovations, while doing away with the long-standing scissors distortions and even permitting Hicks' specific input subsidies for further inducement on behalf of innovations. All this is to be virtually self-financed by a compensatory lump sum tax (best called a land tax, to emphasize the socialist fact of nationalized ownership of all means of production, including most notably land, instead of hiding behind the sham institution of collective ownership) at a minimal cost to the treasury or to the consumer's subsistence budget. A great drawback to the post-Mao price incentive reform is that it will aggravate an already unsatisfactory and worsening income distribution in the Chinese countryside. Procurement prices are now dramatically higher than before 1979. They do wonders for the rich collectives but little or nothing for those producing just enough, or less, for the members' own consumption. Policies of binding the peasant to his native village, of self-reliance for localities, and of allocating new inputs to areas of high response have caused the problem of spatial disequilibria (common to all countries) to become cumulative in China. The scheme presented in the paper alone will not solve the problem but will keep it in check. With 100–200 million peasants already at or near the nutritionally critical level, Peking can stand little further skewing in income distribution. Disavowal aside, the "grain question" remains central to China. Presence of increasingly well-to-do families, urban or rural, means diversion of grains from direct human consumption to feed and other usage for production of meats and other commodities with high income elasticity. It leads to diversion of land from grain production. In either case, scarcity of grains for subsistence consumption by the poor is increased.

There is no evidence to suggest that the new policy directions also meant abandonment of the old values and goals that underpinned the development strategy. On the contrary, the weight of the evidence seems to point unmistakably to continued validity of the nation-building design. A number of constraints and imperatives will continue to hold, posing quandaries for Peking's reformers. The quandaries in the domain of farm price reform are formidable, with incentives for producers of wage goods and key industrial crops and the political economy of a subsistence guarantee competing for price policy considerations. Price reform without a compensating presence of a land tax is not likely to deal effectively with both requirements. The tax, which should be of a lump sum character, together with continued rationing and price control of the subsistence goods, may be expected to ensure the integrity of the key macro aggregates that flow from the imperatives of the development strategy even while new price incentives produce desired output increases. By permitting replacement of incentives for coercion while producing results consistent with macro requirements, the proposed scheme removes the *raison d'etre* for collective farms. Thus, it permits full rediscovery of the family farm instead of the present tentative return to it which, by retaining the old quotas, threatens to limit benefit and escalate cost.

China's present leadership already has taken several major steps in price and organizational reforms; the additional steps considered necessary or advisable in this paper are not unthinkable even within the framework of the old development strategy. And there are good reasons to believe that Deng and his associates will not be content with what are now half-measures which have given rise to considerable chaos, and that they will summon the necessary courage and clear thinking to take the remaining steps as outlined. In these terms, China will continue to impose restraint on consumption to ensure subsistence for all through rationing and control of consumer prices of necessities. Agricultural performance in output and productivity growths should improve over the historical record under incentive household farming. But material incentive programs for the economy at large (and the "second economy," in particular) will increase demand for high-income elasticity farm commodities at a pace above the historical norm; so that, in food balance terms, China is almost certain to continue to import grains but in quantities probably not any more unmanageable than they are now (Tang 1980a). Our earlier study made from the vantage point of 1979 already took into account—though not as fully as one might now—the reforms then on the way. And there are new insights into Chinese demographics. But the food gap, as earlier projected for 2000, is not likely to change much because of offsetting changes in demand and supply projections warranted by the new light. For those with a craving for numbers, we suggest a net annual import of 15–30 million tons by 2000.

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Food versus Feed and the Dynamics of the World Food Situation: Discussion

Charles Y. Liu

I do not have major conceptual or methodological differences with any of the papers. What is intended here is to supplement Dr. Mellor's paper, since his analysis excluded the People's Republic of China (PRC), and to elaborate on Dr. Tang's paper.

Basically, China's agricultural development faces the same problems the other developing countries have encountered, namely, a large population to feed, backward agricultural technology, large rural sector, and a poor natural endownment. In addition, China suffers from the consequences of thirty years of isolation and the aftereffects of past dogmatic ideology.

Since 1976, China's current leadership has embarked on a pragmatic course of modernization of the economy. Therefore, the Chinese agricultural development should be looked at in two distinct periods: 1949–76 and 1977 to date. Some of the notable agricultural policies in force today include:

(*a*) putting the order of economic priority as agriculture, light industry, and heavy industry, with emphasis also on energy and transportation sectors;

(*b*) raising standards of living in rural and urban areas by raising personal income, by producing more consumer goods and less capital goods, and by subsidizing the gap between the recently raised procurement prices and the retail prices of agricultural products;

(*c*) decentralizing more production and managerial decision making down to basic production units instead of relying on orders from the central government;

(*d*) implementing, on a large scale, a material incentive production system rather than relying on ideology as in the past;

(*e*) allowing the expansion of private sector by enlarging the size of private plots and opening rural free markets—as a result, the rural income derived from this activity has increased from 25% of total in 1979 to possibly as high as 40% currently;

(*f*) being willing to import large amounts of farm goods, especially grains and cotton, in order to satisfy rising demand;

(*g*) emphasizing science, technology, economics, and management; and

(*h*) strictly enforcing population control.

Because of these policies much progress was made in agriculture between 1977 and 1980. Table 1 presents a rough comparison.

In addition, population growth rate was reduced to about 1.1% in 1980. Per capita income for a commune member from collective distribution, which had increased from 43 yuan in 1956 to 63 yuan in 1976, rose to 85 yuan in 1980, a similar increase in just four years.

Using Mellor's measure for other developing countries, China's demand for farm goods also far outpaced the supply in spite of the fast growth of production in the 1977–80 period. Despite recent developments, the PRC falls in the very low income group on the basis of the population in the rural sector (still over 80%), and also on income elasticity of demand groups, In contrast, the high rate per capita income growth puts China in the high income group, and the low rate of population growth falls in the very high income group.

On a broader perspective, negligible dependence on foreign energy and other raw materials, relatively effective bureaucratic and party organization in carrying out the central planning orders, and flexibility by the central leadership level in adjusting economic course when encountering difficulties in meeting targets and implementing policies all contributed to what was achieved during 1977–80.

However, China's rapid economic growth and progress is not totally without problems. These problems stem from not just any single cause but from a wide variety of factors. China experiences problems caused by serious natural, technological, institutional and eco-

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Table 1. People's Republic of China: Agricultural Growth Rate

	Production		Area		Yield	
	1956–78[a]	1977–80	1956–78[a]	1977–80	1956–78[a]	1977–80
	(% per annum)					
Grain	2.6	4.7	−0.2	−0.9	2.8	5.6
Cotton	1.5	9.7	−1.0	−0.3	2.6	10.1
Oilseeds[b]	−0.1	11.2	−1.5	5.2	1.4	5.7
Edible oils	1.2	14.5				
Meat	3.7	15.6				

Sources: Surles and Tuan, USDA.

[a] Calculated from the averages of 1955–57 and 1977–79.

[b] Including soybeans.

nomic constraints. China, though slightly larger than the United States, cultivates only about 10% of the country's total land mass and cultivated area is substantially less than that of the United States. The prospect of reclaiming new land is not good, and it would be very costly.

Virtual isolation from the West since 1949 and particularly during 1966–76 (cultural revolution) has reduced technological advance in agriculture to near bottom both in terms of the caliber of researchers as well as the basic research system and structure. Therefore, technology transfer at a reasonable speed is seriously hampered. Without this, notable increase in yields from the present level cannot be expected in the near future.

The institutional setup for agricultural production and bureaucratic organization were structured in the 1950s from Soviet design and/or from Mao's ideology, which was more suitable for total central planning. Today, in the pursuit of agricultural modernization, this setup serves more as hinderance than a help to economic growth. For example, when agricultural production increased beyond the point of producing for self-consumption, the government procurement apparatus found itself unable to handle the inflow of farm products from the communes in buying, storing, transporting, processing, and distributing.

Finally, the economic constraint is a severe long-run problem. As more decentralization of production decision making takes place, as the private sector plays a more significant role in the economy, and as producers respond to changing signals from government policy, the Chinese system lacks an effective mechanism, whether it be market or central planning oriented, to deal with the questions of for whom, what, how much, when, where, and how to produce.

In other words, as the agricultural sector moves from the more initial stage of development to the next, production tends to be more specialized, steps between production and consumption increase, distance for product flow lengthens, product form changes become frequent, and interdependency among locations, sectors, institutional levels, inputs and outputs, etc., increase. Without a well-organized system of production, marketing, distribution, and utilization for both inputs and ouputs in the economy, farm sector behavior will likely be more knee-jerk reaction to symptoms than systematic search for cures to the sickness. The recent announcement by China's premier that the current period of economic readjustment will be extended for another three to five years is indicative of the severity of these problems.

Given the above, I hasten to add that these phenomena are not atypical among developing countries. China has made significant progress in only four years despite all these handicaps. Many other developing countries still suffer from the same problems after thirty years.

Now we may look into the next five years or so and stab qualitatively at what might be the agricultural growth in China and also at what effect this growth might have in the world market for agricultural products.

(*a*) Currently China appears to be carrying out a two-tier farm import policy. Chinese are conservative in nature, and China's basic goal is still to strive for minimum dependency on other nations for food. The PRC is willing to import a large amount of grains for the time being in order to devote more effort to the growth of cash crops in the hope that imports for cash crops can be reduced. Then grain imports will be lowered to an acceptable level. There are already signs of success in cotton and oilseeds production toward this end.

(*b*) The growth of agricultural production during the eighties will drop sharply from the very rapid growth rates experienced in the late seventies. However, growth of production for most commodities will be somewhat above historical growth rates (as measured by the growth of production between 1955–57 and 1977–79).

(*c*) Growth of production in per capita terms will be substantially in excess of historical rates because of slower population growth. Population growth during the eighties may be lowered as rapidly as planned. A conservative estimate would be 1.1% per year. This compares with an historical rate of 1.9% per year.

(*d*) The rate of growth of production for most cash crops will drop somewhat as the eighties progress. This is due largely to diminished opportunities for increasing area at the expense of grain.

(*e*) Grain production during the eighties will grow at a lower rate than that for 1977–80. Coarse grain production should grow most rapidly because of rapid growth of yields and some increase in area.

(*f*) Meat production increases will be significant.

(*g*) There likely will be no significant overall growth in agricultural imports during the eighties. Wheat imports will plateau at about the present level, and coarse grain imports should rise slowly but are not likely to exceed the 1973–74 level.

If the present policy continues, China will remain a significant food importer in the world market in the next few years, but not too much a disruptive factor due to relatively smaller year-to-year variation in food production than the Soviets and its desire to have an orderly development process.

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Food versus Feed and the Dynamics of the World Food Situation: Discussion

Pan A. Yotopoulos

A comprehensive picture of the world food situation must account specifically for the three strategic claimants of the world's food supplies: the less developed countries (LDCs), the USSR, and the People's Republic of China. The three papers, respectively by Mellor, Desai, and Tang, do a creditable job in putting the three components in place. Do they also manage jointly to provide an accurate picture of the dynamics of the world food situation? Past experience with similar global projections is sombering. This paper "postcasts" the record of the recent years, by using the methodology implicit in the authors' projections, for the purpose of seeking explanations for the frailty of global food forecasts.

The starting point of projections makes the time derivative of food a function of the time derivatives of population, per capita income, and relative prices, $\dot{D} = f(\dot{N}, \dot{Y}, \dot{P})$. Algebraic manipulation gives the familiar time-rate relative-change equation,

$$\frac{\Delta \dot{D}}{D} = e_N \frac{\Delta \dot{N}}{N} + e_Y \frac{\Delta \dot{Y}}{Y} + e_P \frac{\Delta \dot{P}}{P},$$

where the subscripted e's are the respective elasticities. The last factor of the equation is the most difficult to handle and becomes the first to be ignored. It will be discussed briefly and last, in recognition of Tang's valiant effort to focus on prices, at least qualitatively. Moreover, it is commonly assumed that the population elasticity of demand is equal to 1, and that the income elasticity of demand is about 0.8, although Tang also considers the values of 0.6 and 0.4 for China (Mellor, p. 75; Tang, p. 35).

Table 1 applies the simplified time-rate relative-change equation and compares the estimates to production and actual demand of all cereals for the period 1961/65 to 1974/76.[1] The results depend very much on the parameter value used for the income elasticity of demand. The commonly used value of 0.8 consistently overestimates demand. The low value of 0.4 appears more appropriate, with the exception of the estimates for China and USSR and those for the DCs when split into two groups. How seriously should we take the result that it is mostly population that drives the world's demand for food, while income enters with a low elasticity of only 0.4?

The Population Component

Although the value of one for the point elasticity of demand for food with respect to population appears plausible on intuitive grounds, it must certainly represent an overestimate of the relevant arc elasticity. The reason is that population is a nonhomogenous variable, consisting, say, of the rich and the poor. Moreover, there are two underlying functional relationships between the respective time-rate derivatives, one between population (birthrate) and income, and another between food demand and income. Both relationships are convex with respect to income. In such a case, adopting an elasticity value of one, that is the average (weighted or unweighted) value of demand, would tend to overestimate the amount of consumption actually taken to sustain the new births.[2]

The intuitive explanation of the bias introduced is simple. There are children born in high-consumption societies and those born to

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[1] The period was chosen so as to smooth out weather-induced fluctuations in production.

[2] Consider two income groups, Y_1 and Y_2 with α and $(1 - \alpha)$ their respective membership proportions. The two situations that arise are $F_1 = f(\alpha Y_1 + (1 - \alpha)Y_2)$ if the birth rate (or consumption) is equally distributed among the two groups; or else $F_2 = \alpha f(Y_1) + (1 - \alpha)f(Y_2)$ if the relation between the dependent variable and income is not strictly proportional. By definition if $f(Y)$ is any strictly convex function we must have $F_2 > F_1$ for α: $0 < \alpha < 1$. This implies that the birth rate is higher under income inequality and the cereal consumption is lower.

Table 1. Annual Rates of Growth, All Cereals, 1961/65 to 1974/76

		Predicted[b]		Actual			
	Number of Countries[a]	$e_Y = 0.8$	$e_Y = 0.4$	All Demand	Indirect (Feed)	Direct (Food)	Production
World	124			2.85	3.70	2.28	2.88
LDCs[c]	98	4.46	3.38	3.37	5.80	2.93	2.97
Low LDCs	34	3.48	2.84	2.76	2.19	2.76	2.56
Middle LDCs	64	5.44	3.92	3.87	5.90	3.11	3.29
DCs	26	4.22	2.56	2.47	3.29	1.31	2.83
Market DCs	20	4.05	2.45	1.66	1.33	2.32	2.58
Centrally Planned DCs	6	4.40	2.67	3.70	7.74	0.34	3.30
USSR	1	4.38	2.74	3.79	8.79	0.44	3.16
China[d]	1	4.21	3.13	2.83	1.78	3.02	3.04

Sources: World Bank, Food and Agriculture Organization, and project file data.

[a] The classification of countries follows the World Bank.

[b] The equation for prediction is $\frac{\Delta \dot{D}}{D} = e_N \frac{\Delta \dot{N}}{N} + e_Y \frac{\Delta \dot{Y}}{Y}$ where $e_N = 1$ and $e_Y = 0.8$ or 0.4.

[c] China is not included.

[d] China's growth rates (for the period 1957 to 1979) were taken at 2.05 for population and 2.7 for GNP per capita.

subsist through life just at this side of hunger—say at less than 2,000 calories per day. The two sets cannot receive equal weights. In fact, 88% of the world's population growth since 1960 occurred in LDCs, and only 12% in DCs. A 44% increase of world population since 1960 requires a less-than-proportional agricultural increase, in global terms, to be fed at the pre-existing levels. The population component of the equation entirely overlooks the variance in demand for food associated with the distribution of births among different income groups.

The Income Component

The income gains in the last two decades far outdistanced the population increases. While population grew by about a half (44%), per capita incomes roughly doubled between 1960 and 1980. The progress in world agriculture was equally impressive: average annual rates of growth ranged from 2.3% (1970–77) to 2.7% (1963–70), which are higher than the rates of growth in population; yet the diets in LDCs barely improved, and the number of undernourished people probably increased (FAO).

The irony of the situation is that in some basic sense the world as a whole, most nations in general and most individuals in particular, are richer today than they have ever been before in the entire span of human history. Yet, the world food problem may be as grave today as it ever was. This obviously never would have been the case if poverty were the principal cause of hunger. In my view it is not. It is relative affluence that is the principal cause of world hunger. This is also precisely the component missing from the time-rate relative-change equation.

To illustrate this controversial point, table 1 breaks down the demand for cereals into indirect (feed) and direct (food, industrial, and others) use. This breakdown is a central point of all three authors. Desai, for example, projects feed grain use separately for USSR. Mellor emphasizes the importance that livestock products play in keeping the income elasticities of demand high. This distinction is useful because cereals represent the staple commodity for both ends of the income distribution, for the poor and the rich. Cereals (wheat, rice, and coarse grains) are the major source of calorie intake in most LDCs. In fact, at a relatively low level of subsistence, cereal consumption is a good proxy for nutritional adequacy. In DCs, cereals again feature prominently in the human diet. The only difference is that coarse grains are consumed indirectly, having been fed to a rather inefficient protein converter, the ruminant stomach. The relevant calorie-equivalent, grain-meat conversion rates vary from 2 ÷ 1 for poultry to 7 ÷ 1 for feedlot-fed beef.

The problem with estimating demand for cereals—even worse, demand for total gross value of agricultural production—without distinguishing the poor and the rich, and direct and indirect cereal consumption is precisely that the former is bounded while the latter is not. There is only so much cereal that can be consumed directly to provide an adequate nutritional intake—something less than 200 kilograms per capita per year. The variance is much higher when indirect cereal consumption is also considered, with the average per capita rising to 550 kilograms per year in Western Europe and 850 kilograms per year in the United States. "During 1975 *per capita* indirect consumption of cereals for feeding livestock was 361 kg in developed countries which was more than 15 times the equivalent figure in developing countries. In fact, on a *per capita* basis, more than twice as much cereal was fed to animals in developed countries as was fed to human beings in developing countries" (Islam).

Examination of the breakdown of demand into direct and indirect use in table 1 adds emphasis on certain elements of the "Dynamics of the World Food Situation" that are present, but diffused, in the three papers.

(*a*) With the few exceptions that appear in the disaggregations to be discussed below, the rate of growth of indirect cereal use far exceeds the rate of growth of direct consumption. For the first time in history the world food system is literally driven by animals!

(*b*) All LDCs grouped together fit the above characterization. Disaggregation into low- and middle-income LDCs reveals a problem that aggregates mask. In the former, the rate of growth of direct cereal use is greater than the indirect. In the latter, the discrepancy in favor of indirect use increases. The difference may lie in the distribution of income and population gains among the low and middle income classes. The low income LDCs, starting from universally low nutritional standards and relatively equal distribution of poverty, translate most income and population gains primarily to direct (food) consumption. The middle LDCs have a growing middle income class that has a high income elasticity of demand for indirect cereal use.

(*c*) Contrary to middle income LDCs, the middle income classes in the market DCs have reached consumption levels of animal protein that warrant little further improvement as a result of income gains. Income inequality, on the other hand, makes for substantial increase in direct use of cereals by low income classes as incomes grow.

(*d*) The socialist DCs and China illustrate two opposite cases of relative (nutritional) egalitarianism. In the former, the direct demand for cereals is pretty well met universally, and most of the increase in demand originates with indirect consumption—the improvement in diets. China has started with lower nutritional standards, and, as a result, most of the change occurs in direct cereal consumption and a modest (equally distributed?) gain in indirect use.

(*e*) The socialist DCs and China are egalitarian societies (when it comes to basic nutritional levels) and also command economies with direct rationing mechanisms. As a result, they could readily deny the expression of the income elasticity by stopping the improvement in diets and so decrease the rate of demand to equal the increase in agricultural production. Should the crunch come, Russia could unhook itself from agricultural import dependence—something that can never be captured in Desai's import functions.

(*f*) In contrast to socialist DCs and China, most LDCs are characterized by unequal income (nutritional) distribution and market orientation. They have large low income classes who still try to increase their direct consumption, and they have people at the other end of the distribution who are constrained by the price mechanism alone from "shrinking" cereals (at the rate of, say, 7 : 1) for indirect consumption as animal protein. Further use of price as an effective rationing mechanism in this case probably would create serious problems for the poor, since the two cereal markets—feed grains and soft grains—are linked. In the extreme case, the animals for the consumption of the rich may crowd out the direct demand for the subsistence of the poor.

(*g*) The LDCs, if they continue on the present course, are bound to increase their import-dependence on the DCs. The reason is not so much that agriculture is lagging behind—although it could still perform better by growing, say, at a rate of 3.7% per year which FAO considers feasible—but that the diets of those who can afford it are being improved at a staggering rate. The 5.80% annual rate of increase in indirect cereal consumption is the result of the incomes explosion of the main beneficiaries of development—the growing middle income class and the affluent.

Conclusion

Anthony Tang quotes Charles Shuman that: "Hunger is not a technical necessity, it is an economic phenomenon. There are no hungry people where there is money to buy food." This may sound tautological. But it cannot be a tautology because it is wrong! More than an economic phenomenon, hunger is a social phenomenon which has to do with the absence of a minimum threshold level of distributive equity. It may be that a minimum of direct intervention in basic food consumption is the only way to limit the income elasticity of the wealthy from crowding out the demand of the poor. In the meanwhile, projections of demand that ignore the underlying income distributions are bound to be unstable.

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International Trade and Agricultural Labor Markets
(Alex McCalla, University of California, Davis, Presiding)

Trade in Products and International Migration in Seasonal Labor Markets

Robert D. Emerson

Alien workers have become an issue of increasing concern in the United States in recent years. Were there not limits upon permanent immigration to the United States, there would be no "illegal" problem. Nevertheless, the presence of legal temporary and illegal workers in the United States reflects an excess demand for certain types of labor in U.S. labor markets and an excess supply of such labor in the sending labor markets. The issues addressed in this paper are the relationships between agricultural product markets and agricultural labor markets for seasonal products, particularly in relation to international movements of products and factors of production. A theory of the operation of seasonal agricultural labor markets in the United States will first be given. I will then consider the contributions of the theory of trade in interpreting the current migration of labor into the United States. Specific agricultural labor markets in which there are foreign workers will then be addressed as they relate to the theme of trade and migration.

Seasonal Labor and Production in Agriculture

A salient feature of most agricultural production (with the exception of some livestock production) is that it is marked by seasonal variations in activity in contrast to an industrial assembly line production stream. Throughout most of agriculture, the seasonal peaks in activity at planting and harvest time have been met by increased mechanization, such as in the grains. Mechanization has also eased the seasonal activity in a number of fruit and vegetable crops as well. Examples are in cherries and beans. Yet, there remain a number of fresh fruit and vegetable crops which are hand harvested utilizing, with existing technology and factor prices, large amounts of labor over a fairly short duration of time.

Because of climatic conditions, a number of fresh vegetables such as tomatoes can be grown domestically only in southern regions such as Florida during winter months. As the year progresses, climatic conditions are no longer suitable in these areas and production moves north in the summer. Coincident with the crop cycle variations are large seasonal variations in the demand for labor. For example, hired employment in Florida varied from a high of 111,000 persons in April 1980 to a low of 59,000 persons in July 1980 (Florida). Such a large variation is further compounded by the fact that many of the areas in which such crops are grown are rather isolated from large population centers.

Because of the remote nature of many production areas, few workers can be anticipated from local labor markets at the prevailing wages. While some may be drawn into the labor force on a part-time basis, it is not reasonable to expect many to give up full-time jobs for seasonal harvest work in agriculture. The labor market response to the local seasonal shortage is the temporary attraction of domestic migratory and foreign workers. (For empirical evidence on agricultural worker response to wage rate differentials, see Emerson.) Moving from south to north with the maturation of crops are the corresponding movements in pronounced seasonal demands for labor. A more formal description of the operation of this labor market follows.

The essential characteristics of the labor markets are illustrated in figure 1 (Spreen). The market for year around or full-time work in agriculture (production jobs, employment in other nonseasonal agriculture) is reflected in panel a. This could be viewed as reflecting the general farm labor market conditions in the

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area, as suggested by a "prevailing" wage rate, w^*.

The harvest labor market has been separated into panel b of figure 1. The effect of the harvest could be considered as a seasonal shift in the demand curve and treated in the same diagram as full-time workers (as long as we can maintain the assumption that the workers are homogenous and actually a part of the same labor market). Although the diagrams are separated, it is assumed that the full-time and harvest labor markets are linked. Specifically, an excess supply in the full-time market could be expected to shift the harvest labor supply schedule to the right. Likewise, an excess demand in the full-time market would be expected to shift the seasonal harvest supply schedule to the left.

The demand for harvest labor (D_h) is specified as relatively inelastic, reflecting the urgent nature of harvesting most fresh fruits and vegetables. The supply schedule for local harvest labor (S_l) is also specified as being highly inelastic: workers have to be drawn from other full-time work or drawn into the labor force on a temporary basis. As illustrated, there would be a substantial shortage of harvest labor from local sources at the prevailing wage of w^* determined for full-time workers. Clearly, seasonal harvest needs could be met by local workers only, but only with a sharply increased wage rate as reflected in panel b, and the wage rate w_{lh}. Instead workers are attracted from other areas as reflected by the supply schedule for migratory workers, S_m. This schedule is specified as somewhat more elastic than the local harvest supply schedule. (For supply elasticity estimates, see Emerson, Walker, Andrew.) The total harvest supply relation is the horizontal sum of the local and migratory supply schedules, yielding an equilibrium harvest wage rate and employment level, L_h. The quantity L_{lh} is local harvest workers and the remainder are migratory. The equilibrium wage is w_h, illustrated here as slightly higher than w^*, the wage rate for full-time workers. While it is conceivable that the wage could be lower than w^*, observation suggests that it is typically higher.[1]

The supply curve S_m consists of both

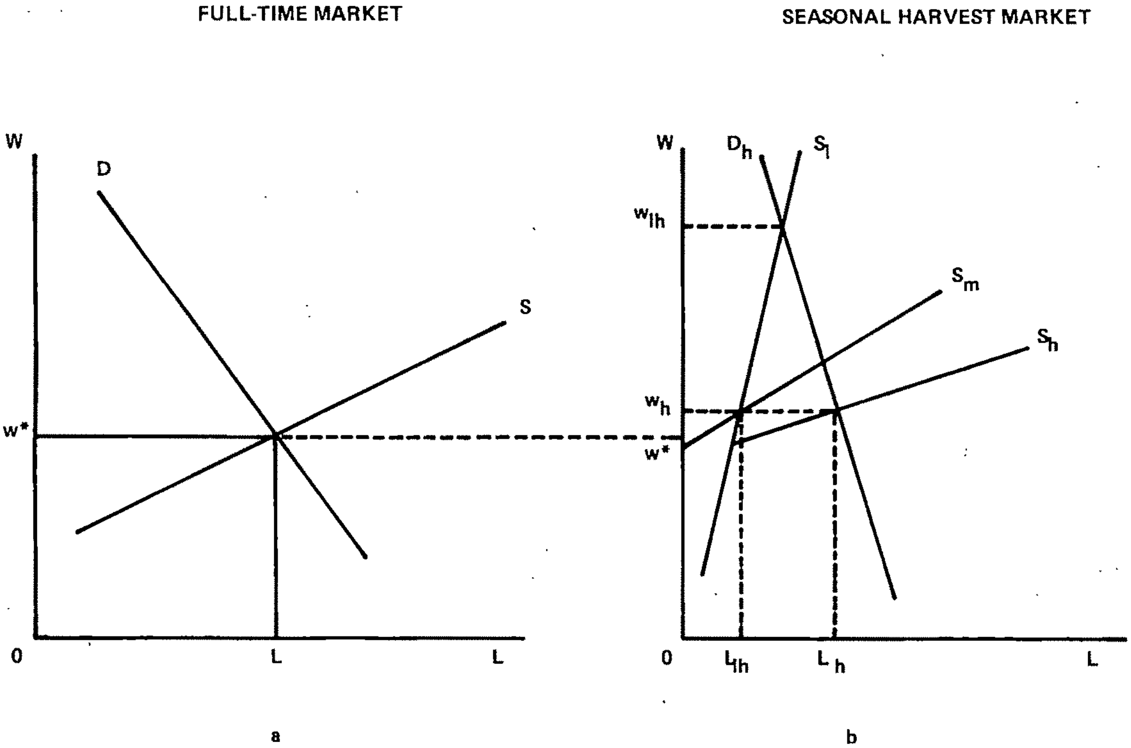

Figure 1. Essential characteristics of full-time and seasonal harvest labor markets

domestic and foreign migratory workers. Although these could be illustrated with separate supply schedules, the implication remains the same that sharp variations in seasonal demand provide incentives for labor migration, both domestic and foreign. Clearly, one means of reducing foreign migration is to reduce the demand for labor. Importing seasonal products rather than producing them domestically would be one alternative. We turn now to a consideration of the relationship between trade in goods and factor mobility.

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[1] Harvest workers are paid predominantly by piece rate. The average piece rate (converted to an hourly rate) was \$4.92 versus \$4.62 for all farm workers in Florida in January 1981. The April 1980 difference was even wider: \$5.15 for piece rate workers versus \$4.39 for all workers (Florida Crop and Livestock Reporting Service).

Trade and Migration

Jones recently capsulized the theory of trade as follows: "The bulk of the theory of international trade has dealt with the case where all factors are trapped and, from Ricardo's time to date, the moral of the concept of comparative advantage has been that any nation can find something for its productive agents to do that will allow them successfully to compete in world markets for the wares they produce" (p. 257). While trade theory is a very rich theory, as Jones suggests, much less consideration has been given to the implications of factor movements than to the trapped factor case.

The state of trade theory as it relates to factor mobility was succinctly stated by Mundell nearly twenty-five years ago and is worth repeating here:

> Commodity movements are at least to some extent a substitute for factor movements. The absence of trade impediments implies *commodity*-price equalization and, even when factors are immobile, a tendency toward *factor*-price equalization. It is equally true that perfect mobility of factors results in *factor*-price equalization and even when commodity movements cannot take place, in a tendency toward *commodity*-price equalization.
>
> . . . an increase in trade impediments stimulates factor movements and . . . an increase in restrictions to factor movements stimulates trade. (1957, p. 321)

In a subsequent revision of this paper, Mundell modified the leading statement to read, "Commodity movements and factor movements are substitutes" (1968, p. 85).

The basic theorem on factor-price equalization following from commodity-price equalization from free trade stems from Samuelson. Among the limiting assumptions are that each country has the same production function subject to returns to scale. It is assumed that there are no factor intensity reversals regardless of the factor price ratio, and furthermore, specialization does not take place prior to commodity price equalization. If these assumptions are satisfied with the two-country, two-commodity, and two-factor world, then factor price equalization between countries follows directly.

Mundell proceeded to demonstrate the impact of relaxing the assumption that capital was immobile between countries (1957, pp. 322–26). He assumed two countries *A* and *B* producing two commodities, cotton and steel, with the two factors, labor and capital. Country *A*'s capital-to-labor ratio is lower than country *B*'s, and cotton is labor-intensive relative to steel. Assuming no impediments to trade and immobile factors, it follows that *A* will export the labor-intensive good, cotton, and import the capital-intensive good, steel.

Consider figure 2, where *TT* is the product transformation curve and *U* is the social indifference curve for country *A*. Under a free-trade environment, production would be at point *P* and consumption would be at *Q*, resulting in *A* exporting cotton and importing steel. Suppose now that country *B* decides to place a tariff on all cotton imported, and for simplicity, let it be prohibitive. (The tariff is placed on the opposite good in the opposite country as compared to Mundell's 1957 paper.) Then *A* must revert to an autarky position, such as *R*. Production of steel would expand, production of cotton would fall. Since cotton is labor-intensive, there will follow an excess supply of labor in country *A* relative to the position with free trade. Wage rates would thus be expected to fall accordingly.

Simultaneously, the opposite effects would result in country *B* with production shifting toward cotton and away from steel. Consequently, there would develop an excess de-

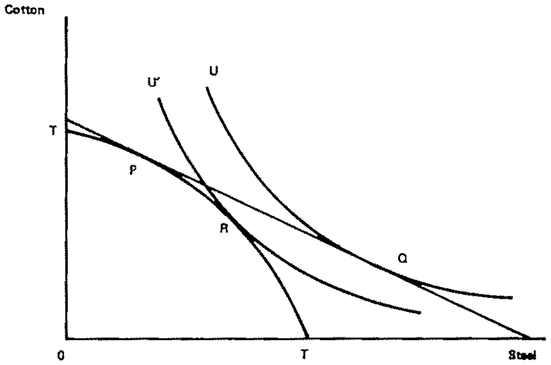

Figure 2. Country A

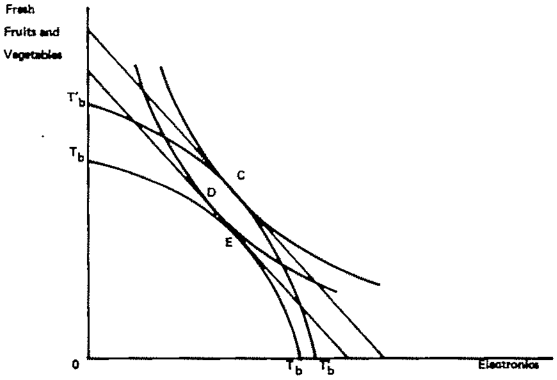

Figure 3. Country B

mand for labor in country *B*, with a subsequent rise in wage rates. Prior to the tariff, under the assumed conditions, both countries would be producing at points where the marginal productivities of the respective inputs were the same. The result of the tariff is to drive a wedge between them.

In the presence of trapped factors of production, such a wedge results in pressure for either labor or capital to migrate between the two countries until net rewards in the two countries are equalized. Permitting labor to be mobile, we would expect to observe labor migrating from country *A* to country *B* in this case. In the absence of free mobility of labor, there will be a pent up pressure for migration from *A* to *B*. While the world has been greatly simplified by the assumptions in the above model, the essential characteristics apply to Mexico as country *A* and the United States as country *B*. In place of cotton, we might consider fresh fruits and vegetables; in place of steel, perhaps electronics.

Although labor mobility is clearly not officially sanctioned between the two countries, it nevertheless has taken place on a rather large scale. In a world of free mobility, migration would continue until marginal products were equalized in each country. In the illegal case, migration would stop short of the full equalization of marginal products due to the additional costs of labor movement and the risk of apprehension and detention or deportation.

Mundell's analysis is also suggestive of a means by which a domestic economy could return to production with only its own resources. Consider figure 3, where $T'_bT'_b$ represents the production possibility curve after the migration of labor to *B* from *A* subsequent to the tariff that was discussed above. Thus *B*'s resource base has been augmented. Furthermore, assume that it has been augmented to the point where migration has stopped because of equalization of marginal products.

The initial point is thus one of no trade reflected by point *C*, the equilibrium point on the augmented transformation curve. Suppose now that free trade is reinstated. There will be no movement from point *C* because marginal products and commodity prices will have been equalized due to factor mobility.

Country *B* now decides that foreign labor is undesirable and decides to tax the earnings of foreign workers. The result is a reduction in the net returns of foreign labor in *B*. Consequently, foreign labor will leave country *B*, returning to country *A*. Country *B*'s production contracts to the transformation curve T_bT_b. In the absence of trade, the price of fresh fruits and vegetables would rise relative to the price of electronics. But with free trade, *B* will import fresh fruits and vegetables in exchange for electronics. Production would be at *E* and consumption at *D*. Thus, the factor market restriction has induced trade in products to restore product and factor price equality.

In the context of the United States and Mexico we have both trade and factor mobility impediments. Focusing merely on the fresh fruit and vegetable market, the above would suggest that one step in alleviating immigration pressures would be to remove the tariff on fresh fruits and vegetables. An additional step potentially to reverse the flow of workers and return to a national work force would be to tax the earnings of foreign workers in the United States. The extent to which these actions would actually remove the stimulus for further migration to the United States would require further analysis, given the presence of other distortions in both economies. Nevertheless, that there is a trade-off between product and factor market trade impediments has been missing from most considerations of the alien labor issue. (The work of Hiemenz and Schatz is an exception to this.)

Welfare Considerations

A recent paper by Bhagwati and Brecher sheds additional light on welfare gains and losses in open economies with foreign-owned factors of production. The above discussion has proceeded from the assumption that a nation was only concerned with either equalization of factor prices or impeding factor movement into, or out of, the country. Bhagwati and Brecher approach the question of determining the impact of trade policy on domestic factors in the presence of foreign-owned factors.

A standard result of trade theory is that an improvement in the terms of trade will improve the welfare of the nation. Bhagwati and Brecher caution that in the presence of foreign-owned factors of production, such an improvement in terms of trade may actually reduce the welfare of the nationally owned factors. The necessary conditions for this to occur are what they label a differential-trade-pattern effect. They contrast an economy operating with national factors only versus one with both domestic and foreign factors of production. The differential-trade-pattern that they identify results when movement from autarky to free trade implies trade in opposite directions in the presence of foreign factors of production versus production with only domestic factors.[2] If this differential-trade-pattern effect is sufficiently strong, the welfare of domestically owned factors may be reduced as a result of free trade. Empirical evidence would be helpful in identifying the likelihood of this possibility.

Jones arrives at essentially the same result as Bhagwati and Brecher regarding the welfare of domestically owned factors. (p. 256) He considers countries in which foreign nationals and foreign capital are combined with domestic labor and capital to produce traded goods. The impact of a commodity price change on domestic remuneration is then intertwined with the share of domestic versus foreign-owned resources in the production of each good.

Jones' paper asserts that recognition of international mobility of factors of production limits the inferences which can be drawn on the basis of the law of comparative advantage. Jones closes his paper with the following statement: "Once trade theorists pay proper attention to the significance of these internationally mobile productive factors, the doctrine of comparative advantage must find room as well for the doctrine of "relative attractiveness" where it is not necessarily the technical requirements of one industry versus another that loom important, it is the overall appraisal of one country versus another as a safe, comfortable, and rewarding location for residence of footloose factors." (p. 258).

Although there remain uncertainties related to distributional issues with mobile factors, there appears to be little question among economists that trade in products substitutes for factor movements. However, with complete freedom of factor mobility and immobile technology, as Jones asserts, a country with inefficient technology may not be able to attract any resources for production. The degree to which this can be avoided is an important question in an increasingly shrinking world.

Agricultural Trade and Seasonal Labor Demand

Agricultural products of major interest in the context of this paper are sugar, apples, tomatoes, citrus, and fresh vegetables. Among these, further distinctions are necessary concerning the seasonal potential for trade.[3] Among fresh fruits and vegetables, the major geographic area of interest is Mexico and other Central American countries and the Caribbean nations. They are sufficiently close to ship products for the fresh market and also have a temperate to sub-tropical climate permitting them to produce tomatoes and vegetables during the winter season when it is not feasible in most areas of the United States. By the same token, production of vegetables in these areas virtually ceases during the warmer season when northern areas of the United States come into production.

Winter production is feasible in both the United States as well as Mexico and Caribbean areas; the primary consuming market is the United States. Consequently, increased domestic production suggests decreasing foreign production and diminished demand for Mexican and Caribbean labor. Assuming a world of trapped factors, the United States would have an excess demand for labor, Mexico and the Caribbean an excess supply of labor. This situation in the labor markets would suggest an increased incentive to migrate to the United States during the winter season. Likewise, a diminished level of domestic production would be expected to yield the opposite results, increasing Mexican and Caribbean employment and reducing the demand for labor in the United States.

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[2] This applies to the case when neither the domestic only nor the domestic plus foreign factors have resulted in specialization for the same product price ratios. For the other cases of specialization, see Bhagwati and Brecher.

[3] I use the term "potential for trade" as the possibility of both regions producing the product in the same season. This is in contrast to the more common usage to reflect an improvement in the terms of trade.

Consider now alternative means of equilibrating labor and product markets. Imports from Mexico and the Caribbean are not feasible in the summer months. One option is to balance U.S. seasonal labor needs through domestic migration. If not explicit, this has been our implicit policy by maintaining the limited H-2 temporary labor program. However, the mobility of goods and factors remains tied together across seasons as well as within season. For example, if all of our winter vegetables were imported, domestic migratory labor would have diminished employment opportunities during the winter season. Alternatively stated, there would be an excess supply of domestic migratory labor; it would be more difficult to piece together a year-round employment pattern through migrating. In the extreme case, there would be no domestic offsetting seasonal variations in labor demand.

The trade model would suggest that an alternative is trade in products during the winter season, but mobility of labor across the borders during the summer. Whether or not this is desirable depends upon the respective product and factor prices, technologies, and tastes and preferences. The important point, however, is that the seasonal production areas are intricately tied together across the seasons through the labor markets.[4] It should be noted that a potential result of increased imports of tomatoes during the winter months could be increased use of foreign labor due to a reduction in domestic mobility. However, this does not deny the existence of increases in welfare through such an arrangement.

Domestic citrus production, unlike vegetables, is located only in the warmer climates. It is also distinct in that the harvest is an extended period lasting several months. In contrast to vegetables, the fruit can be stored on the tree without rapid deterioration. Although citrus is not produced in northern areas of the United States, other tree crops, such as apples and cherries, are harvested there in late summer.[5] The domestic seasonal labor demands tend to balance in a similar fashion to the vegetable case considered above.

Citrus is also produced in Mexico and Caribbean areas, thus suggesting a situation similar to the vegetable case. There is the potential for importation of citrus, with a consequent reduction in demand for labor during the winter season. The result would again be an excess demand for labor by other domestic tree crop producers. The latter effect could be resolved through a combination of three different mechanisms: (*a*) an increase in the wage rate, (*b*) increased use of foreign workers, or (*c*) increased price of the product, reducing the market-clearing quantity.

The seasonal use of labor in sugar is unique to Florida. Beet sugar is largely mechanized. Likewise, cane sugar in Louisiana and Hawaii is mechanized. Florida's combination of weather and muck soils have impeded the extent to which its cane is mechanically harvested. British West Indies workers have come to Florida under the H-2 program on a regular basis to plant the cane and harvest it by machete. Growers are annually certified by the Department of Labor that domestic labor is not available for the harvest, although one could easily argue that at some wage rate, labor would be forthcoming. Moreover, even if this priced Florida out of the market, sugar is widely available on the world market, not uncommonly at prices below the domestic price. However, as suggested by Welch, once the industry is in place as it is, the loss of secondary employment (processing, for example) may exceed any potential gains to domestic harvest workers. The question of who would gain or lose as a result of the termination of the program would be particularly informative.

It is clearly unreasonable to expect that wage rates between the United States and Mexico would be equated with the types of adjustments resulting from shifts in agricultural production suggested as possible here. Nevertheless, it should be clear that the existing impediments to trade in the products discussed above serve to motivate foreign workers to migrate to the United States for agricultural work and increase the demand for low cost (foreign) workers in the United States. (See Zepp and Simmons for information on trade impediments on vegetables.) Furthermore, the focus of this paper has been restricted to seasonal agricultural product and labor markets. A much larger portion of entrants is believed to be in nonagricultural production, e.g., the service industry, the garment industry.

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[4] The assumption that the harvest labor market for vegetables is distinct from that for other products is a gross simplification. Nevertheless, the first-order effects would be in the same direction.

[5] The matching of seasonal demands across regions with similar crops is in accordance with observed work patterns; few seasonal workers work in both tree crops and vegetables. This does not deny, however, that with the appropriate wage structure workers would not do both types of work.

Capital Mobility

Major attention has been given to the tradeoffs between labor mobility and trade in products. Equally important is the mobility of capital. In a world of factor mobility, a disequilibrium leading to labor mobility could equally be satisfied by a flow in the opposite direction of capital. In fact, most of the trade literature dealing with factor mobility has considered the case of capital mobility (Mundell). The interest is currently in labor mobility because of the large number of entrants who have found their way into U.S. labor markets.

Consider the relatively capital-rich country placing a prohibitive tariff on the labor-intensive good, thereby moving from free trade to an autarky position. With capital mobility, capital would flow to the country well endowed with labor. With labor mobility, labor would flow to the capital-rich country. With mobility of both factors, each factor would move in opposite directions until equilibrium were again achieved.

In the context of the United States and Mexico, for example, capital mobility is sanctioned to an extent. Mexico has had the 51% rule assuring Mexican nationals of control of capital investments. Such restrictions increase the risk of foreign investment in a country such as Mexico and impede the flow of capital. Other important considerations are the potential for immiserization resulting from foreign investment (Bhagwati and Tironi).

Concluding Comments

The theme of this paper has been that trade and international labor migration are intricately linked. Increased trade impediments induce labor and/or capital mobility. The fairly simplistic models considered suggest that free trade could reduce the incentives for migration to the United States for harvest work during the winter season. By the same token, it could lead to increased migration during the summer season. Whether or not this would lead to a welfare improvement in either or both countries would require much more detailed empirical analyses of the product and labor markets in the respective countries.

This paper has not given adequate attention to the problems of growth and development as related to trade (see, e.g., Johnson). In this sense, the discussion is biased toward the United States. A major issue is how trade can benefit countries such as Mexico or Caribbean nations. This becomes particularly acute when factor mobility is permitted. It is fairly clear that if the United States were to open its doors for immigration, or at least for work, there would be a vast movement from Mexico and particularly Caribbean nations to the United States. A true advocate of open markets would find no problem with this mobility and suggest the gains that would follow. However, the prevalence of public assistance programs in the United States poses a serious domestic problem for this approach.

In the absence of permanent immigration, temporary work programs such as the H-2 program or guestworker programs are a means of permitting labor to migrate legally. A concern about guestworker programs is often that the host country gains at the expense of the source country. (But see Bhagwati and Brecher for considerations on how the domestically owned factors could possibly lose.) The individual who migrates for work from either Mexico or Jamaica to the United States faces wages several times higher than in his home country. Individual gains clearly have the potential for being large. The way in which the funds are used upon return to his home country is particularly important. But significant domestic market distortions can nullify potential gains to the guestworkers' home economy if earnings are used for consumption rather than investing in human or physical capital.

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Employment Implications of Exporting Processed U.S. Agricultural Products

David Blandford and Richard N. Boisvert

The importance of international trade in the U.S. economy has increased dramatically in recent years. Between 1970 and 1980, merchandise exports rose from 3.9% to 8.4% of gross national product (U.S. Department of Commerce 1971, 1981). The growth in international markets has been particularly significant for agriculture. In 1970, exports accounted for 14.4% of the value of farm marketings, while by 1979 they had increased to 24.3% (U.S. Department of Agriculture 1980).

Much of the interest in the recent growth in agricultural exports has focused on its implications for the balance of payments and farm incomes. Less attention has been given to the question of whether the United States is realizing the maximum gains for the economy as a whole from foreign market opportunities. One way to address this broader question is to examine the contribution of agricultural exports to national employment and income, recognizing that such exports generate economic activity throughout many sectors of the economy. The nature and distribution of this activity depend not only on the total volume of commodities but on the form in which they are exported.

The current administration has expressed a desire to increase the proportion of agricultural commodities exported in processed form and is intensifying its efforts to promote such products overseas (*Washington Agricultural Record*). Work has been initiated within the U.S. Department of Agriculture (USDA) to examine the potential for expanding processed exports and the employment implications of such expansion (Schluter and Clayton). The purpose of this paper is to complement these efforts in order to assist policy makers in assessing the implications of expanding processed exports. The analysis is placed into perspective by first examining the recent historical importance of primary and processed agricultural exports and the nature and allocation of U.S. expenditure on foreign market development. Next, the employment contribution of major categories of processed exports is estimated, and finally the major policy implications derived from this information are identified.

Trends in Agricultural Exports

Data on U.S. agricultural trade are readily available. In most cases, a useful distinction can be made among the primary commodity (or commodity group) and its first- and second-stage processed forms. For example, wheat can be exported in its primary form as grain, after "first-stage" processing in the form of flour, or after "second-stage" processing as a component in packaged food products. Corn, on the other hand, could be exported directly as grain, as part of a prepared feed mixture, or embodied in livestock.

Recent trends are examined for major commodity groups by aggregating available data in terms of primary agricultural commodities and their counterparts at a "first-stage" of processing. The aggregates in table 1 do not account for agricultural products that constitute a small proportion of the value of numerous manufactured exports. For example, the primary oilseeds category includes soybeans, cottonseed, and other oilseeds; the processed category includes vegetable oils, meals, and oilcake. Primary livestock includes exports of live animals, whereas the processed livestock category includes carcasses, meats and meat products, and animal by-products. Other categories are defined using parallel distinctions between primary and processed forms. There are two categories of processed agricultural exports in table 1 which are not reported in the agricultural export data, although they embody a substantial component of primary agricultural product and are therefore consistent with the above notion of first-stage processing.

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Yarn and cloth comprise the bulk of processed cotton exports, while processed tobacco includes cigarettes, pipe tobacco, and other manufactured tobacco products.

Table 1 contains the value of primary and processed exports in 1973 and 1980 for eight major commodity aggregates. Nominal values were deflated by the corresponding components of the U.S. wholesale price index to convert to 1972 constant dollars. The average annual growth rates reported in the table are also based on constant dollar values.

After accounting for inflation over the 1973–80 period, the total value of exports in the categories listed increased from $11 billion to $19 billion. This represents an average annual growth rate of just over 8%. The growth rates for primary and processed products were roughly the same. In each of the years, 72% of the total value was made up by primary products and 28% by processed products. The tremendous increase in U.S. exports of primary feed grains and oilseeds during the 1970s is generally acknowledged; interestingly, processed exports as a group kept pace and continue to constitute a significant portion of the total.

In 1973, developed countries (DCs) absorbed 63% of all U.S. agricultural exports. By 1980, this proportion had dropped to 52%. While some of this change is explained by a small relative increase in exports to centrally planned countries (CPCs), the major shift has been toward markets in less developed countries (LDCs). This shift is particularly pronounced for processed exports; in 1973, only 26% of processed exports were destined for LDC markets, whereas by 1980 this percentage had risen to 43%. There are several forces which have contributed to this marked expansion; rising incomes in many LDCs over the period, coupled with their lack of primary processing capacity, are certainly contributing factors. From a policy perspective, this change in the distribution of products across markets is as significant as the change in their total volume.

Market Promotion

Despite the fact that the rapid increase in agricultural exports is a relatively recent phenomenon, U.S. government activities to maintain or expand overseas markets date back at least to 1953, with the creation of the Foreign

Table 1. Principal Exports of Primary and Processed Agricultural Products by the United States

	1973 Value of Exports				1980 Value of Exports				Average Annual Growth Rate of Value of Exports (1973–80)[c]
		Distribution[a]				Distribution[a]			
Commodity Group	Total	DC	LDC	CPC	Total	DC	LDC	CPC	
	($mill. 1972)	--------	(%)	--------	($mill. 1972)	--------	(%)	--------	(%)
Primary									
Food grains	2,350	26	53	21	3,303	23	55	23	4.9
Feed grains	2,287	72	16	12	4,716	56	28	16	11.8
Oilseeds	1,531	86	8	6	3,064	79	15	6	10.3
Livestock	125	80	18	2	93	76	24	0	−4.6
Poultry	13	48	52	0	25	36	62	2	9.1
Fruits and vegetables	341	86	13	1	539	76	24	[b]	5.1
Cotton	574	44	43	13	1,211	35	39	26	10.4
Tobacco	684	84	15	1	743	71	26	2	—
Subtotal	7,905	61	27	12	13,694	53	32	15	8.2
Processed									
Food grains	137	5	95	0	138	2	98	[b]	—
Feed grains	22	56	44	0	33	38	62	0	4.4
Oilseeds	809	64	17	18	1,576	44	41	15	9.1
Livestock	1,001	71	23	6	1,535	62	33	6	8.2
Poultry	64	65	35	[b]	332	33	65	2	22.5
Fruits and vegetables	468	75	24	1	815	53	45	1	6.1
Cotton	254	NA[d]	NA	NA	298	NA	NA	NA	—
Tobacco	279	NA	NA	NA	518	NA	NA	NA	11.4
Subtotal	3,034	66	26	8	5,245	50	43	8	8.1
Total	10,939	62	27	11	18,939	52	35	13	8.2

Sources: U.S. Department of Agriculture 1974–81, U.S. Department of Commerce 1974–81, U.S. Department of Labor 1973–81.

[a] Destination of exports by region. DC is developed countries; LDC is less developed countries; CPC is centrally planned countries as defined by the USDA. Percentages for subtotals and total are weighted averages using export value shares. Processed cotton and tobacco are excluded.

[b] Less than 0.5%.

[c] For individual commodity groups, computed from semilog trend line and only quoted if the null hypothesis of zero growth was rejected at the 10% level or above. For subtotals and total, computed as the compound growth rate implied by 1973 and 1980 values.

[d] NA means not available. Detail may not add due to rounding.

Agricultural Service (FAS). Since its inception, the FAS has undertaken a variety of programs to facilitate sales of U.S. agricultural commodities overseas. Many of the agency's promotional activities are carried out jointly with market development co-operators. These are primarily farm-oriented groups representing specific commodity interests. Within the co-operator program, two basic approaches have been used. Trade servicing, the provision of information on price, availability, usage, and technical application of U.S. products in overseas markets, is particularly well-adapted to bulk, unprocessed commodities. Consumer promotion, the use of media advertising and other techniques to promote generic or brand-name products, is generally used by co-operators representing producers of semi-processed and processed products.

In table 2, FAS co-operator program expenditures are allocated between primary and processed products. Unpublished data on expenditures by co-operator and by country were available on a fiscal year basis. Funds provided to each co-operator were allocated entirely to the primary or processed product category corresponding to the co-operator's major commodity interest. The resulting distribution is approximate because some co-operators undertake activities relating to both the primary commodity and its processed counterpart. However, the allocation was applied consistently, and the relative difference in expenditures by category and market between the two years is therefore less sensitive to errors in classification.

According to the table, FAS expenditures through the co-operator program totaled just over $9.6 million in fiscal 1974. By fiscal 1980, they had increased by 76%. Although it would be difficult to adjust this increase to reflect the change in the purchasing power of these dollars overseas, the U.S. wholesale price index increased by roughly 71% over the same period. This suggests that real expenditures have been relatively constant. Although the figures indicate the federal government's contribution, they do not represent the total resources devoted to market promotion through the co-operator program. Unpublished data suggest that federal funds are supplemented by approximately $2.5 of co-operator and foreign third party contributions in the form of cash or goods and services per dollar of FAS expenditure. These are not included in the table because their distribution by market was unavailable to the authors. Based on the figures for FAS expenditures alone, it appears that the share devoted to processed commodities has declined in recent years. On the other hand, the share allocated to product promotion in LDCs has increased.

The reduction in the proportion of FAS expenditures devoted to processed products through the co-operator program is explained by a shift to other promotional activities. These expenditures have increased from 10% to 18% of the total between fiscal 1974 and 1980 and support trade offices, multicommodity programs initiated by FAS and the Export Incentive Program designed to promote branded products. (See McKinna for details.) The distribution of these expenditures has also shifted towards LDC markets, but the shift

Table 2. Foreign Agricultural Service Expenditures on Market Development Programs

	Fiscal 1974					Fiscal 1980				
			Market Distribution[a]					Market Distribution[a]		
	Expenditures		DC	LDC	CPC	Expenditures		DC	LDC	CPC
	($1,000)	(%)	------- (%) -------			($1,000)	(%)	------- (%) -------		
Co-operator program										
Primary[b]	7,213	67	77	23	0	13,619	66	70	30	0
Processed[b]	2,421	23	90	10	0	3,378	16	92	8	0
Subtotal	9,634	90	80	20	0	16,997	82	74	26	0
Other programs[c]	1,104	10	94	4	2	3,689	18	72	23	5
Total[d]	10,738	100	82	18	0	20,686	100	74	25	1

Source: Unpublished USDA (FAS) data.

[a] See table 1.

[b] Funds used by FAS co-operators, allocated according to their major commodity focus.

[c] Expenditures on trade offices, projects initiated by FAS and Export Incentive Programs. (See McKinna for description.)

[d] Excludes expenditures which could not be allocated regionally, accounting for 1% of the total in 1974 and 4% in 1980.

has been more dramatic than in the cooperator program.

Exports and Employment

The rapid expansion of agricultural exports implies that overseas sales are of growing importance to U.S. agricultural producers. This direct linkage is the primary motivation underlying the market promotion activities of the FAS. However, it is also desirable to identify the returns to promotional activities for the nation as a whole. A complete evaluation is beyond the scope of this paper, but would involve two major components. One component is an assessment of the effectiveness of public expenditure in expanding overseas markets. The second is the determination of the benefits derived from such expansion by agriculture and other sectors of the economy. The remainder of the paper contributes to this second component.

In assessing the economy-wide benefits of export expansion, one would need to estimate the net returns to all factors of production attributable directly or indirectly to agricultural sales overseas. A major consideration is the implication for employment, particularly in light of recent increases in the unemployment rate. The number of jobs generated throughout the economy depends not only on the total volume of agricultural exports, but also on the degree to which they are processed prior to export.

An interindustry analysis for the U.S. economy is used to estimate the domestic employment attributable to agricultural exports. The analysis is based on the 1972 detailed input-output table, the most recent one available from the U.S. Department of Commerce. This table divides the U.S. economy into nearly 500 sectors and delineates their purchases of individual commodities. Using procedures outlined by Su, transactions were estimated on a commodity-by-commodity basis. Based on this reformulation, it is possible to determine the direct input requirements per dollar of output on a commodity rather than an industry basis. This procedure eliminates the problems created by secondary products in the usual industry-by-industry delineation and facilitates an aggregation consistent with the primary and processed agricultural commodity distinction introduced above.

An aggregate table containing forty-five sectors was constructed for the analysis. Eighteen sectors were designed to correspond as closely as possible to the agricultural commodity aggregates delineated in table 1. The remaining sectors were combined into twenty-seven aggregates, containing one or more sectors of the economy defined by the two-digit SIC industrial classification (Executive Office of the President).

Within the model, exports to foreign countries are treated as exogenous additions to final demand. Accordingly, one can calculate the level of sales of all commodities throughout the economy (s_j) generated by a particular dollar value of export sales of commodity j (x_j) from

$$(1) \qquad s_j = \sum_{i=1}^{n} c_{ij}\, x_j,$$

where c_{ij} is the i,jth element of the Leontief inverse $(I - A)^{-1}$, A being an $n \times n$ matrix of the dollar value of input i per dollar of output j.[1] This information, combined with estimates of the direct employment generated per dollar of output for each commodity i (w_i), can be used to calculate the direct and indirect employment throughout the economy (e_j) attributable to a particular dollar value of export sales:

$$(2) \qquad e_j = \sum_{i=1}^{n} w_i\, c_{ij}\, x_j.$$

Employment data for 1972 from *County Business Patterns* were used extensively to estimate direct employment coefficients (U.S. Department of Commerce 1973). These data are organized on an industry basis rather than by commodity. To adjust the figures to reflect the commodity structure of the input-output table, the Commerce Department's data on the make of commodities by industry were used to reapportion total industry employment (U.S. Department of Commerce 1979). In the case of primary agricultural products, employment figures are not available from *County Business Patterns* (CBP). Data from Merrill were used.

The employment coefficients generated in this fashion must be interpreted with some care. CBP figures cover 76% of all civilian wage and salary employment and are a count of employees during a single pay period. There is no way to determine how much of the employment recorded is full-time rather than part-time, or to assess how much seasonal employment is included. The implication of partial coverage is that the employment impact of exports will be understated. The inclusion of part-time employment may partially offset this understatement.

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[1] The model assumes that the household sector is exogenous, that is, consumer final demand is unaffected by changes in household income. This is an unrealistic assumption for a national model and implies that the sales attributed to exports are understated. Data were not available to the authors to close the system with respect to households. However, the underestimation of total sales is proportional across sectors (Bradley and Gardner) and an intersectoral comparison of the relative impact of exports on employment is unaffected.

One way to assess the importance of agricultural exports from an employment perspective is to estimate the total number of jobs in the economy attributable to exports using equation (2). Table 3 contains such estimates for 1973 and 1980 exports, measured in constant 1972 dollars to be consistent with the valuation in the interindustry table. Between these two years, the estimated number of jobs due to agricultural exports increased from just under 0.9 million to roughly 1.4 million or by 68%. In both years, approximately three-quarters of these jobs were attributable to primary exports. This is close to the proportion that such exports represented of the total. As might be expected, the distribution of the jobs created by primary and processed exports differs across sectors of the economy. For processed products, two-thirds of the total employment generated is in agriculture, whereas for primary products it is almost 80%. The difference reflects the value added from other sectors in processing.

Table 3 provides an important historical perspective on the contribution of primary and processed agricultural exports to employment. However, given the administration's interest in the expansion of processed exports, it is necessary to compare the net employment effects of expanding the eight categories of such exports. The net effect is computed by estimating the total employment attributable to $1 million of processed exports and then by netting out the employment contribution of the primary commodity embodied in the processed export. That is, the total employment effect is reduced by the number of jobs that would have been generated had the embodied primary commodity been exported in unprocessed form. Algebraically, the net employment effect ($e_p{}^*$) is

$$(3) \qquad e_p{}^* = \left[\left(\sum_{i=1}^{n} w_i c_{ip}\right) - \left(\sum_{i=1}^{n} w_i c_{iu}\right)(c_{up}/c_{uu})\right] x_p,$$

where w, c, and x are defined as in equations (1) and (2), the subscript p denotes an agricultural processing sector, and the subscript u denotes its corresponding primary sector. The term $\Sigma w_i\, c_{ip}$ is the direct plus indirect employment per dollar of processed exports; the term $\Sigma w_i\, c_{iu}$ is a similar expression per dollar of primary exports; c_{up}/c_{uu}, the ratio of two elements of the Leontief inverse, estimates the equivalent dollar value of unprocessed exports per dollar of processed exports.[2]

Table 3. U.S. Employment Generated by Major Agricultural Exports

	Direct Plus Indirect Employment[a]				Employment Generated by Sector as Percent of Total[b]			
			Percent of Total			Agriculture		
Commodity Group	1973 Exports	1980 Exports	1973	1980	Year	Primary	Processed	Other
	-- (1,000 Jobs) --							
Primary	652	1,074	75	74	1973	78	[c]	21
					1980	77	[c]	23
Processed	213	375	25	26	1973	45	23	33
					1980	46	21	33
Total	865	1,449	100	100				

[a] Derived from the 1972 detailed input-output table of the U.S. economy, U.S. Department of Commerce 1979; independent estimates of 1972 direct employment coefficients based on data from U.S. Department of Commerce 1973; Merrill; and the constant dollar export figures given in table 1. The input-output table was structured on a commodity-by-commodity basis and was reaggregated to reflect the 16 primary and processed agricultural sectors in table 1. The reaggregation was accomplished by an algorithm from Boisvert and Bills.
[b] Represents the percentage of direct and indirect employment that is generated in agriculture and other sectors of the economy.
[c] Less than 0.5%.

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[2] Schluter and Clayton calculate the net employment from exporting a million dollars of primary product in processed form. Their approach, although logically consistent with the one above, was not used in this paper because it makes the direct comparison of the expansion of different categories of processed exports more difficult.

Table 4. Change in Employment from Processing Agricultural Exports

	Processed Agricultural Exports		Equivalent Primary Agricultural Exports		Net Change in Employment Distribution[b]			
						Agriculture		
Commodity Group	Value	Direct and Indirect Employment[a]	Value[b]	Direct and Indirect Employment[a]	Total[c]	Primary	Processed	Other
	($1,000)	(Jobs)	($1,000)	(Jobs)	(Jobs)	(%)		
Food grains	1,000	57	128	8	49	8	55	37
Feed grains	1,000	56	198	13	43	20	29	51
Oilseeds	1,000	58	513	27	31	28	25	47
Livestock[e]	1,000	75	287	18	57	51	20	29
Poultry[e]	1,000	102	186	11	91	41	31	28
Fruits and vegetables	1,000	71	110	15	56	8	40	52
Cotton	1,000	90	63	9	81	1	68	31
Tobacco	1,000	64	203	44	20	1	49	50

[a] Derived from the 1972 detailed input-output table of the U.S. economy (see table 3).

[b] Dollar value of unprocessed agricultural exports embodied in $1 million of processed agricultural exports. It is calculated from the ratio of two elements of the Leontief Inverse (c_{up}/c_{uu}), where u refers to the unprocessed sector and p refers to the processed sector.

[c] Column 2—column 4.

[d] Represents the percentage of the net change in employment generated in agriculture and other sectors of the economy.

[e] The primary export component is feed grains and oilseeds rather than primary livestock or poultry. Thus, the net employment is attributable to the livestock and poultry producers as well as processors.

The data in table 4 demonstrate that the total number of jobs created by an expansion of processed exports by $1 million (1972) differs substantially across commodity groups. It ranges from a low of 56 for feed grains to a high of 102 for poultry. The total employment effects are lowest for processed grains and oilseeds. The net effects differ in terms of their relative ranking, although poultry still ranks highest. The smallest total effect is in feed grains, but the smallest net effect is in tobacco. Much of this difference is due to the relative values of the primary agricultural commodities that would be exported in unprocessed form. In general, where the equivalent value is low (as it is in food grains), the net effect tends to be closer to the gross effect. A contributing factor to the high net effects in poultry and livestock is the way in which their primary agricultural component is defined. For these commodities, the appropriate comparison is not the export of live animals versus processed meats and poultry. Rather, the relevant alternatives are the export of feed directly or feed embodied in livestock products, because exports of live animals are dominated by breeding stock. Thus, the equivalent primary agricultural export (e.g., $287,000 in the case of livestock) is the value of embodied feed grains and oilseeds.[3] Because exporting processed rather than primary feed grains is also an alternative, a category for processed feed grains was included in the analysis.

The treatment of livestock and poultry partially explains why the proportion of the net change in employment going to primary agriculture is considerably higher than for other commodities. For example, over 40% of the net effect for poultry is in primary agriculture because raising poultry is viewed as the first stage in the indirect export of feed. However, the proportion of the net change in employment going to primary agriculture varies across the other commodity groups as well and appears to be inversely proportional to the degree of processing involved.

Policy Implications

The policy implications of this analysis follow from the observations made above regarding export trends, promotional expenditures, and employment. The first observation is that in recent years, processed agricultural commodities have made a significant contribution to the total value of U.S. agricultural exports. Despite the rapid growth in primary exports since 1973, processed exports have kept pace, maintaining a share of roughly 28%. The principal factor sustaining the 8% annual growth rate in processed exports has been a tremendous expansion in sales to LDCs. Second, during the same period, federal government market promotion expenditures through the FAS have shifted towards LDC markets, but preliminary estimates suggest that the share of expenditures allocated to processed products has tended to decline. Third, processed products account for roughly 25% of the total number of jobs generated by agricultural exports in the U.S. economy. Because of the additional value added in processing, there would be a net increase in employment if for each agricultural commodity a larger proportion of its total exports were in processed form. The magnitude of the net increase differs by commodity as does its distribution between production agriculture and other sectors of the economy.

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[3] This procedure entailed a slight modification of equation (3) by subtracting the employment attributable to the equivalent dollar value of two primary inputs. This more complicated calculation could have been used generally to net out all embodied primary agricultural commodities in processed exports. In the majority of cases, primary inputs other than those corresponding to the major commodity group were insignificant and were therefore ignored.

From a policy perspective, recent experience demonstrates that opportunities for expanding processed agricultural exports have been realized. Rates of export expansion equal to or above the average for all primary commodities have been experienced for several processed products: poultry, tobacco, oilseeds, and livestock. It is difficult to assess whether historical growth rates will be sustained in the future, or the extent to which market promotion programs could increase them. Nevertheless, these commodities deserve careful examination. For example, processed poultry exports grew at an average annual rate of over 22% between 1973 and 1980. Furthermore, the export of feed embodied in poultry rather than in its raw form generates the highest net employment effect per million dollars of processed exports of all the commodities considered. Efforts to sustain or expand overseas markets for processed poultry would clearly merit close consideration. On the other hand, processed tobacco, whose exports grew at an annual rate of over 11% between 1973 and 1980, has the lowest net employment impact by far of all the commodities examined. It is less than one-fourth of that for poultry. From a national employment perspective, efforts to expand processed tobacco exports seem to be of lower priority than other commodities where the net employment effects are higher.

In evaluating the relative merits of export expansion for processed products, the distribution of the net change in employment may be an important consideration. The distribution among the agricultural processing sector, primary agriculture, and other sectors of the economy differs considerably across commodities. For example, if one were particularly concerned with job creation in primary agriculture, the expansion of livestock exports would rank high in that an estimated 51% of the net increase in employment accrues to primary agriculture (table 4). On the other hand, only 8% of the net increase in jobs for fruits and vegetables is generated in primary agriculture. Yet, in terms of their net impact on national employment, the two commodity groups are virtually identical. This comparison suggests that the promotion of processed agricultural exports based solely on their contribution to employment in production agriculture may not be the best strategy for maximizing the net increase in employment nationally.

In conclusion, the analysis in this paper has been designed to provide information useful in evaluating the desirability of promoting exports of broad categories of processed agricultural commodities. Its focus is on how to utilize net employment information in evaluating export expansion, recognizing that there are numerous other considerations involved in formulating policy. The interindustry methodology used in the paper does not incorporate resource constraints on production for export. Historical growth rates are only partial indicators of future market potential. A more complete evaluation of export promotion strategy would have to include an in-depth assessment of the numerous economic and institutional factors which affect the prospects for growth in overseas markets for processed agricultural products. It is particularly important to identify the effectiveness of promotional expenditures in expanding the demand for both primary and processed products. With this information, it would be possible to determine the extent to which the net employment contribution of processed export expansion could be increased through the allocation of promotional expenditures.

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International Trade and Agricultural Labor Markets: Farm Policy as Quasi-Adjustment Policy

D. Gale Johnson

I start from the assumption that an important objective of agricultural policy, including international trade policy for agricultural products, is to increase the incomes of the farm population. In particular, I assume that the most important component of income in evaluating whether agricultural policy meets this objective is the labor incomes of the farm population. Obviously real-world agricultural policies have additional objectives, such as food self-sufficiency, stability of food supplies and prices, and retaining a larger rural and agricultural economy than would obtain if market forces were permitted to determine product prices. The objective of a larger farm economy may be viewed in terms of the paths over time of farm employment. Presumably if this objective is achieved, the decline in the farm labor force and population would be slowed down and, at a given time, both would be significantly larger than if there had been no significant intervention in farm product markets.

The major industrial countries have followed quite different agricultural price, income, and trade policies in the post-World War II period. The differences in the policies provide us with an opportunity to determine, at least approximately, what differential effects there have been on the welfare of those people who have maintained some attachment to agriculture. These policies have resulted in strikingly different prices received by producers, especially in the period since 1960.

Admittedly, the objective of keeping employment in agriculture at a higher level than would otherwise be the case is seldom stated explicitly. This objective is often stated in other terms, such as maintaining the farm way of life or of keeping viable rural communities. The method or technique that is used to influence positively the number of persons making their livelihood from farming is through increasing the demand for resources that are used in agriculture.

The increase in the demand for resources is generated by increasing product demand. Product demand can be increased for a given geographic area by limiting imports through tariffs, import quotas, or variable levies, by expanding exports through payment of export subsidies, or by making direct payments that are output-related and supplement product prices. The increase in resource demand can be reflected in higher resource prices and/or increased employment of resources. As is well known, a given increase in product demand will have the greatest effect on resource prices for those resources that have the lowest price elasticities of supply and the greatest effect on employment for those resources with the largest price elasticities of supply. These are very simple propositions, but they appear to be generally ignored in the promulgation and analysis of agricultural policies.

The substantial differences in the product prices, and thus the product demands, among the major industrial countries provide us with an opportunity to understand how resource prices and employment have been affected. I shall compare and contrast the effects upon the return to farm resources and farm families of the agricultural and trade policies of the European Community (EC), Japan, Canada, and the United States.

This paper is based upon a particular analytical framework. The framework starts from the theoretical and empirically supported conclusion that economic growth, as measured by growth of per capita incomes, results in a decline in the relative importance of ag-

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riculture in the economy of a geographic area and, eventually, in an absolute decline in the employment of labor in agriculture. The theoretical underpinnings for this conclusion are obvious and well known. They derive from the empirical facts that the income elasticities of demand for farm products are less than unity and thus less than the average for the rest of the economy, and that these income elasticities decline over time relative to those in the rest of the economy. The second important relationship is that productivity change in agriculture since World War II has been, for the industrial economies, at least as rapid as in the nonfarm sector of the economy. Thus slower productivity growth has not served to offset the slower growth of demand for farm products.

Under conditions of economic growth, if farm people are to share in the benefits of economic growth, real agricultural wages must increase over time at the same rate as nonagricultural wages (Johnson 1973b). And if there are few barriers to labor mobility, farm labor earnings will increase at approximately the same rate as nonfarm labor earnings. In fact, it appears that during the past three decades the barriers to mobility or, more specifically, the costs of mobility have declined in the high income countries. This has been due to the reduction in the costs of transportation and of acquiring information. The general availability of the automobile or bus plus the improvement and extension of roads has sharply cut the costs of both moving and commuting. Further, the costs of information have been sharply reduced through the nearly universal availability of radio and television and the telephone, as well as the printed media. Thus over the past three decades it is probable that in the industrial countries farm labor earnings have increased relative to nonfarm labor earnings simply because the equilibrating costs have fallen over time. The equilibration has been an added element in reducing farm employment.

There are a number of implications that flow from this analytical framework. One is that if agriculture is organized primarily on the basis of family farms, the average size of farm as measured by area will increase over time. This conclusion assumes that farm size is permitted to adjust with few or no extra-market restraint. In one of our countries, namely Japan, growth in farm size has been limited by legal interventions. The Land Reform Law made land renting very difficult, and the sale of farm land to other farmers was severely restricted. Farm size as measured by land area changed rather little for more than three decades; under some circumstances this might well have constituted a barrier to the improvement of farm labor returns. However, as we shall see later, the labor adjustment in Japan took a particular form and, while this adjustment did not result in efficient or low cost agricultural production, it did result in rough equality between the returns to farm and nonfarm labor of comparable quality.

In *World Agriculture in Disarray,* I advanced two propositions concerning the interrelations between the level of farm prices and farm employment and farm labor income (pp. 198–203). One of the propositions was that a constant degree of protection was not enough to have a significant effect upon the return to farm labor. In other words, high output prices can have only a temporary effect in increasing the return to labor. The second proposition was that in the long run, by which I meant something like five years, the level of product prices would have some effect upon farm employment but not upon the return to farm labor. By the end of five years the once-and-for-all effect of the higher output price on the return to farm labor would be eroded by a short-run reduction in the rate of outmigration from agriculture and the continuing growth in the real return to nonfarm labor. Thus, in order to maintain the labor earnings differential prevailing before the output price increase, it soon becomes necessary to return to the same rate of reduction of the farm labor force that prevailed prior to the output price increase.

The adjustments and changes in agriculture in the industrial countries during the past quarter century can only be described as remarkable and unprecedented. Labor productivity in agriculture grew at rates substantially greater than in the rest of the economies; labor forces engaged in agriculture declined at rates that would have been difficult to imagine before World War II. In all of our dozen countries, except Japan and Ireland, the number of farms declined markedly. Another common aspect of the adjustment, as will soon be clear, has been the sharp increase in the integration between the farm and nonfarm labor markets. Due to this degree of integration, nonfarm or off-farm income of farm operator families exceeds the income from agriculture in the majority of the countries.

Three Decades of Agricultural Adjustment—The United States

At the end of World War II there was quite general agreement among economists that agricultural adjustment and the incomes of farm families would be best served by setting price supports at relatively low levels. By relatively low levels were meant price supports that would be effective only a minority of the time. In fact, the phrase "stop loss levels" was used at the time, meaning that the price supports were to be effective only when market prices fell to low levels. The general agreement on the merits of giving significant freedom to the market to function found expression in the Agricultural Act of 1948. Unfortunately, this act never was permitted to go into effect. President Truman's surprise victory in the 1948 election was due, to some degree, to his belated rejection of the 1948 act which he had signed into law. What amounted to new legislation was passed in 1949, and price supports were set at what turned out to be high levels. I use the term high levels to mean price supports at above the level at which supply and demand would be equated (Cochrane and Ryan).

The results were the accumulation of large stocks and the discouragement of exports. When exports declined, the first policy reaction was the expansion of food aid and the payment of export subsidies on commercial sales. These were not enough to generate the required markets. Starting in the late 1950s price support levels were lowered, and by 1966 price supports for most commodities were at or below international prices. The market proved far superior to the government in finding new and profitable commercial markets for our farm products.

The competitive pricing of major farm products was associated with the significant growth in our agricultural exports during the latter part of the 1960s and the early 1970s. By the beginning of the 1970s it was apparent that U.S. agriculture had regained the comparative advantage it had lost for most of the period since the early 1920s. The export growth was due to a number of factors—the devaluation of the dollar, expansion of grain imports by the centrally planned economies and increased food import demands by the rapidly growing middle-income developing countries.

The competitive pricing of the farm crops was accompanied by direct payments to farmers. In the late 1960s and early 1970s the direct payments were often a large fraction of the market price; in the case of wheat there were several years when such payments were equal to half or more of the farm price (Johnson, 1973b). But after 1973 payments were reduced substantially and only occasionally represented a significant source of income. This was true even though the real levels of price supports for wheat, cotton, and corn in the late 1970s and the early 1980s were half or less of the levels a quarter century earlier.

There can be no question that during the 1950s and 1960s U.S. agriculture was burdened with excess resources. There were more resources engaged in agriculture than could earn a return equivalent to that earned by comparable resources in the rest of the economy. The excess resources consisted very largely of labor, though there was significant abandonment of farmland between 1950 and 1970 (USDA ESCS). In a monograph written in late 1972 I argued that most of the excess resources in agriculture had by that time been withdrawn from agriculture (1973a, pp. 36–49). This had been accomplished through adjustments in the labor market and by the abandonment of farmland in certain regions.

Prior to 1950 labor market adjustment in agriculture had occurred primarily through migration from farms, but starting in the 1950s part-time nonfarm employment played an increasingly important role in labor adjustment. In 1950 the farm population (farm operators plus farm workers who reside on farms) received 31% of their total family incomes from nonfarm sources. The importance of nonfarm income in total income increased to 39% by 1960, to 53% by 1970 and to 63% by 1980 (USDA ERS, p. 112).

With the growing importance of nonfarm incomes for the farm population, the per capita disposable income of the farm population as a percentage of the same measure for the nonfarm population increased from less than 40% in 1940 to about 75% at the beginning of the 1970s and to an average of 91% for 1975–79.

The growing importance of nonfarm income to farm operator families is indicated by the approximate percentage of such families that receive more than half of their income from the farm they operated. In 1960 there were 2.1 million farm operators or 53% of the total receiving half their income from their own farm. By 1970 the number had dropped to 951 thousand, or 32% of the total number of farms, and a decade later there were 665 thousand farms (27% of total farms) with half or more of their income from farm sources (USDA ERS, p. 106).

From 1950 to 1976 the number of farms declined by 52%; farm employment declined by almost the same percentage. As noted in my introduction, in an agriculture organized primarily as family farms and where there are no legal restrictions as in Japan, the decline in farm employment may be approximately matched by the decline in the number of farms. An increase in farm size is an effective way to achieve the decline in the ratio of labor to all other inputs that makes it possible for the value of the marginal product of those workers who remain in agriculture to increase at a rate approximately the same as the increase in real wages in the rest of the economy. In the United States agricultural adjustment has occurred while the real price of farm products has been declining at approximately 1% annually (USDA 1977, 1980).

What role has the rapid growth in agricultural exports had in the adjustment process in the United States? This is the question to which I shall now turn.

Growth of Agricultural Exports and Adjustment

During the 1960s the volume of agricultural exports increased by barely a fifth, while farm production increased by only a tenth (USDA 1977, pp. 571, 576). During the 1970s agricultural export volume nearly doubled, while farm production increased by a quarter. During the 1960s farm employment declined by about 35%; during the 1970s the reduction was only 5%.

It was during the 1960s, when exports increased rather slowly, that farm employment declined most. But it was also during the 1960s when there was very substantial progress made in reducing the differential between the per capita disposable income of the farm and nonfarm populations. At the beginning of the decade the farm income was 53% of the nonfarm; at the end of the decade the percentage was 73. Further substantial progress was made during the 1970s in narrowing the income gap—a three-year average centered on 1979 indicates that farm income was 93% of nonfarm income (USDA ERS, p. 114). Thus, in terms of the absolute percent increases, the relative farm income adjustments during the two decades were quite comparable. The differences in export growth were very different, however, as has been noted above.

These simple comparisons of changes in the United States during two decades raises a question concerning the relative importance of changes in product demand (and product prices) and of the labor market in influencing the incomes of farm people. The remainder of this paper is devoted to a not very sophisticated comparative study of changes in relative incomes of farm and nonfarm individuals in the European Community (EC), Japan, and Canada. The first two have followed significantly different price policies, and thus have had very different product demand shifts, than the United States. Canada has followed policies very similar to ours; I have included it because of the presumption that the rather low density of population in a major agricultural region—the Prairie Provinces—might have limited the effectiveness of the labor market in equalizing farm and nonfarm incomes.

Price Policies

In a relatively brief paper it is impossible to provide a detailed comparison of the price and income policies of the major industrial countries (USDA FAS). But for present purposes such detailed comparisons do not seem necessary. The differences in price levels for major agricultural products are so striking that the other differences in price and income policies pale into insignificance. Table 1 summarizes some information on recent price differences for major agricultural products. For grains and livestock, other than dairy products, prices received by farmers in Canada and the United States have been significantly lower than in the EC and in Japan. While the data given are for the late 1970s, the differentials indicated have prevailed throughout the 1960s and 1970s except that the differentials increased significantly after 1970 for Japan.

The price differences are large enough to have been reflected in an increase in the demand for farm inputs—land, labor, and purchased inputs. I do not address the changes in demands for the inputs directly and, in fact, emphasize the changes in labor employment in agriculture and the growth of off-farm incomes

Table 1. Prices Received by Farmers in Major Industrial Countries ($ per metric ton)

	1970		1979	
	Wheat	Coarse Grain	Wheat	Coarse Grain
Belgium	100	86	212	214
Denmark		62	224	214
France	84	75	232	214
Germany	99	89	274	247
Italy	110	93	231	210
Netherlands	102		212[a]	202[a]
United Kingdom	74	68	160	
Ireland	76			181
Canada	61		117	100
Japan	162	131	770	582
United States	48	52	118	95

[a] 1978.

Table 2. Annual Rates of Decline in Farm Employment, 1955–79 (percentage per year)

	1955–60	1960–70	1970–79
European Community	−3.2	−4.6	−3.4
Belgium	−3.7	−4.9	−4.6
Denmark	−2.1	−3.1	−2.7
France	−3.7	−3.7	−4.6
Germany	−3.3	−4.6	−4.8
Ireland	−2.5	−3.0	−3.1
Italy	−3.2	−5.8	−2.2
Netherlands	−2.7	−3.4	−1.8
United Kingdom	−2.5	−3.8	−1.0
Canada	−3.6	−2.7	−0.7
Japan	−2.6	−4.0	−4.1
United States	−3.3	−4.5	−0.5

Source: OECD publications.

as an indicator of the differential impacts, if any, of the disparate price policies. The results that I present are, admittedly, impressionistic.

Changes in Farm Employment

Table 2 presents data on the annual rates of decline in farm employment from 1955 to date. Annual percentage declines in employment in agriculture, forestry, and fisheries are given for three periods—1955–60, 1960 to 1970, and 1970 to 1979 or 1980. The 1960s saw the creation of the Common Agricultural Policy, the significant shift in Japanese price policy, and the shift in the United States to the setting of price supports at levels below anticipated market prices.

For the late 1950s and the 1960s the United States, Canada, Japan, and the EC give no indication that the level of farm prices has a significant effect upon the rates decline in farm employment. For the 1960s Canada has the lowest rate of decline and the EC the highest with the United States and Japan in an intermediate position. For 1970–79 the smallest declines in employment occurred in the United States and Canada; Japan and the EC have significantly larger declines. The lowest rates of decline occurred where the absolute price levels were the lowest.

Table 3 is designed to indicate the relationships between the decline in the number of farms, the increase in average size and the change in farm employment. The data are for 1960–75; 1975 is the latest date for which there are data on number and size of farms. Except for Ireland, Japan had the smallest decline in the number of farms. The large rate of decline in farm employment in Japan was made possible by the facts that in 1960 there were 2.2 workers per farm and the decline in the number of farms that were full-time. In 1960 there were 2,078,000 full-time farms (34.3%); in 1975 there were but 616,000 full-time farms (12.4%). The annual rate of decline in full-time farms was 7.8% (Ministry of Agriculture, Japan).

Labor Adjustment

The declines in farm employment occurred primarily through two processes—migration from farms to nonfarm areas or transferring primary employment from agriculture to nonagricultural activities while continuing to reside on farms. The role of part-time farming in supplementing income from agriculture was noted above in my description of adjustment in the United States.

As noted in table 3, Japan had a relatively small rate of decline in the number of farms; only Ireland had a lower rate. The small rate of decline was due, in part, to the intervention in the land market by the conditions of the land reform law. The labor market adjustment, however, was quite remarkable through reduction in the number of workers per farm. During the first half of the 1950s Japanese farm families obtained about 30% of their net incomes from nonagricultural sources. In 1960–61 almost exactly half of the net income came from nonfarm sources, and by 1971 two-thirds of the net income was from nonagricultural sources (Ministry of Agriculture, Japan).

While I am a great believer in what can be

Table 3. Annual Change in Number and Size of Farms and Agricultural Employment 1960–75 and Number of Workers per Farm 1960

	Change in Number of Farms 1960–75 (%/year)	Change in Average Size of Farms (%/year)	Number of Workers Per Farm, 1960	Change in Agricultural Employment, 1960–75 (%/year)
Belgium	−4.1	+3.5	1.5	−5.1
Denmark	−2.6	+2.3	1.9	−3.1
France	−2.4	+2.4	2.4	−4.5
Germany	−2.8	+2.7	2.6	−4.5
Ireland	−0.5	+1.7	1.4	−2.9
Italy	−1.9	+1.0	2.4	−4.5
Netherlands	−3.1	+2.5	2.0	−2.9
United Kingdom	−3.2	+3.4	2.3	−2.7
Canada	−3.1	+2.9	1.65	−2.2
Japan	−1.3	+1.7	2.20	−3.0
United States	−2.2	+2.2	1.47	−4.6

accomplished in a well-functioning market, I must admit surprise at the growth of importance of nonagricultural income to Canadian farmers, especially in the Prairie Provinces. In 1940 for all of Canadian farm families off-farm wages and salaries equaled 12% of total family net income from farming; by 1970 such off-farm sources of income accounted for 57% of total net farm family income. The ratio of the income of farm to nonfarm families increased from 57% in 1940 to 76% in 1970 (Shaw). The change in the relative income position of farm families in Canada closely paralleled what occurred in the United States.

In 1978 it is estimated that off-farm sources of income were 2.9 times as large as the farm income of farm families in Canada. In Manitoba off-farm income averaged twice farm income; in Saskatchewan off-farm income exceeded farm income; in Alberta off-farm income was four times farm income. These three provinces, of course, are the Prairie Provinces. Approximately half of the farm families in Canada are considered to have primary dependence upon agriculture. Even among these farms, in 1978, 88% had off-farm income, and for all families with primary dependence on agriculture off-farm income accounted for a third of total family incomes (Agriculture Canada, pp. 54, 46).

While off-farm incomes and employment are becoming of increasing importance to farm families in the European Community, farm families have less reliance on off-farm income sources than is true in Canada and the United States and, obviously, Japan. Given the higher density of population in the EC than in Canada or the United States and the much smaller farm sizes, it would seem reasonable that off-farm income would be more important in the EC than in Canada or the United States. But such is not the case.

According to the Commission of the European Communities, "only 27% of all Community farmers have gainful activity outside their own farms, 6% working on other farms and 21% in other sectors" (p. 22). At another point it is stated that "in the Community as a whole some 44% of farmers devote less than 50% of their working time to farming; roughly half of these farmers have no gainful activity other than farming." Some 56% of all farmers in the EC-9 devote 50% or more of their time to farming. The range is from 41% in Italy to 92% in the United Kingdom; in France, Ireland and Denmark from 70% to 78% of the farms the farmer met the full-time criterion.

An OECD study of part-time farming in Germany indicates that between 1965 and 1975 the percentage of full-time farms of total farms increased slightly—from 41% to 45% (p. 27). The percentage of all farms for which farm income was supplementary in the family's income increased from 33 to 39, while the relative importance of part-time farms on which farming was the main source of income declined from 25% to 15% over the decade. The data indicate that for all farms in Germany off-farm income accounts for just 40% of the income of farm families.

Concluding Comments

My paper has admittedly been an impressionistic one. I have not relied upon regressions or even a particularly sophisticated economic model. And I have probably strayed some distance from whatever connection there may be between international trade and agricultural labor markets, let alone "Farm Policy as Quasi-Adjustment Policy."

But I believe that I have assembled evidence sufficient to raise questions concerning the effectiveness of high product prices in either significantly increasing employment in agriculture or in improving the relative income position of farm families. I have not made direct income comparisons, except for brief references to relative incomes of farm and nonfarm families in the United States, Canada and Japan. But the continued rapid outflow of labor from agriculture to the rest of the economy indicates very clearly that high product prices, by themselves, are not sufficient to achieve equality of returns to comparable farm and nonfarm resources. And the available data fail to indicate that relative high product prices have much effect in slowing down the outflow of labor from agriculture. I do not say that there is no effect; the efficient allocation of resources between agriculture and the rest of the economy requires that there be some modest impact of higher product prices upon labor outflow from agriculture.

My review of the income and price situation in the European Community left me with two puzzles, which time permits only mentioning. The first is that there appears to have been little or no success in reducing income disparities among agricultural regions within the EC. Regional income inequalities have been reduced in the United States and Canada over the past quarter century, primarily through adjustments in the labor markets.

In its 1980 report the Commission of the European Communities concluded (p. 52): "During the period from 1964/65 to 1976/77, regional disparities in agricultural incomes (as measured by the gross value-added per agricultural worker) increased in the Community. The ratio between the regions with the highest agricultural incomes and those with the lowest rose from 5:1 to about 6:1." While this statement excludes the effects of off-farm income in reducing income disparities, the modest importance of such income means that regional farm family income differences remain at very high levels.

The other puzzle is the very large differences in the price of farm land within the EC and the rather low prices of land in France and the United Kingdom. Reported prices of land in France in 1979 were substantially below land prices in the American Midwest. English land prices were below the prices prevailing in Iowa or Illinois. Prices in Germany, Netherlands, and Belgium in 1979 were at or near $8,000 per acre.

I mention the puzzle of land prices because I had assumed that a major effect of the high prices for grains and other crop products in the EC would be reflected in high land prices. The Northern EC countries fit my expectations but France and the United Kingdom do not, and Denmark falls somewhere in between. I conclude my paper with this puzzle: What happens to the income from grain prices that are often double the ones that prevail in North America? There is no evidence that they are reflected in higher returns to labor or in significantly higher farm employment. If the high prices are not reflected in higher land prices, the high prices must be associated with inducing high cost of production in terms of the use of inputs other than land.

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International Trade and Agricultural Labor Markets: Discussion

Hans G. Hirsch

The Emerson paper is a good mix of theory and empiricism. In connection with the annual certification by the Labor Department of workers from the British West Indies for harvesting sugarcane in Florida, Emerson raises the question, who would gain or lose from the termination of that program? It has long been held that the labor to perform the demanding and exhausting work of cutting sugarcane on muck soil by machete is simply not available in the United States. Emerson plays with the hypothesis that domestic labor might be found at some higher wage rate. Whether such labor is simply not available domestically, or whether some such domestic labor might be available at a higher wage rate—in either case the same conclusion follows—domestic production factors would marginally lose by being idled or forced into less profitable employment, and foreign suppliers would take up the slack so created.

I shall supplement Emerson's paper by relating my own experience with the termination of the Bracero Program in the mid-sixties. For years, we had admitted Mexican seasonal agricultural labor in rather large numbers into the United States. The statutory authority under which this had been done was permitted to expire in 1965 and the admission of foreign seasonal agricultural labor was greatly curtailed.

The most obvious long-term result of this policy change was that the labor, which could no longer work in the United States, but was dammed up in Mexico, exerted powerful pressures to produce at home. The availability of that labor gave a decisive stimulus to Mexican applications for agricultural development loans to international lending agencies and to our own Agency for International Development. These loan projects have increased Mexican agricultural production, both for domestic consumption and for export. And the exportation of Mexican fruits and vegetables to the United States has certainly increased by leaps and bounds. We can accept this record as proof of the strong postulate originally advanced by Mundell and quoted by Emerson, "An increase in restrictions to factor movements stimulates trade." Nevertheless, it is entirely conceivable that a government may restrict the entry of labor as well as commodities.

In most years, well over half of the cash receipts of American farmers comes from the sale of livestock and livestock products and less than one-half from the sale of crops. By contrast, about 90% of our agricultural exports are crops and crop products and only about 10% are livestock and livestock products. As Blandford and Boisvert argue, crop products, as distinguished from crops, are processed and raise the share of processed products to 28% of total agricultural exports. However, given the different composition of total U.S. farm production, it is not surprising that efforts are made to increase the processed component among American agricultural exports. Moreover, our nonagricultural exports are mostly made up of processed products and, finally, our mercantilist orientation as well as our negative trade balance lead us all in the same direction.

According to the authors, in each of the years 1973–78, 72% of the total value of agricultural exports was made up of primary products and 28% by processed products. I cannot replicate this finding. They worked with export values which they had deflated by the U.S. wholesale price index to 1972 constant dollars. Their deflation should not have affected the relationship of processed products to primary products, unless they applied different deflators to different products. According to the actual, undeflated export values, only 24% of total agricultural exports were processed in 1973. That percentage dropped further to 22% in 1975 but recovered

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to 28% or 29% in each of the four years, 1977–80. I purposely say, "recovered," because prior to 1973 that percentage was still higher, ranging from 30% to 34% during the period 1968–72.

The authors argue that the share of Foreign Agricultural Service expenditures on market development programs devoted to processed commodities has declined in recent years. Their case is not convincingly presented, the less so since they also observe that the share of expenditures in developing countries has greatly increased—from 18% to 25%—and these are the markets where processed products are more important than in developed countries.

The authors drew their conclusion from expenditures for the Co-operator Program. They had no breakdown between expenditures for primary and processed products for other programs. Among these is the Export Incentive Program, which is entirely devoted to processed products. With these other programs included in the breakdown, one-third, or 33%, of Foreign Agricultural Service expenditures on market development programs were devoted to processed products in 1974 and again in 1979 and 1980. During the intervening years, that percentage fluctuated insignificantly between 31 and 34. In earlier years, however—during 1968–73—the percentage was indeed somewhat higher, ranging from 35 to 42. In all the years since 1968, expenditures for processed products exceeded their share of total agricultural exports.

The authors observe—as one would expect—that "the export of feed embodied in poultry rather than in its raw form generates the highest net employment effect per million dollars of processed exports of all the commodities considered." And they conclude: "Efforts to sustain or expand overseas markets for processed poultry would clearly merit close consideration." This is a supply-oriented conclusion. No thought has been given to the fact that technology, know-how, and managerial skill for feeding and processing poultry is transferable and can be acquired by importing and consuming countries. Thus the demand for American labor and management in the field of poultry production—and in other fields of agricultural processing—may be transitional and ephemeral. Indeed, the desire of importing countries to substitute their own domestic labor for the imported labor that is imbedded in the goods imported and their ability to compete in this respect must not be disregarded.

Recent experience suggests still another lesson. In developing and maintaining foreign outlets for our agricultural products, it is of decisive importance to supply what the market demands. If an importing country has oil-milling capacity and is organized to process oilseeds into meal and oil, an inflexible policy to export these processed products instead of the desired unprocessed oilseeds may result in the loss of that market if there is any competition among suppliers at all.

The authors did mention demand at the very end of their paper, but this consideration is given too little weight. I am making this observation remembering an experience I had at a seminar in a German university. My audience told me they were not particularly impressed by any need of American agriculture to expand its exports. What mattered for them was their need for an economic, efficient, and reliable supply of feeds and oilseeds.

Johnson's paper has as a topic the combination of production factors. This idea of combining production factors runs through his paper like a red thread. Unfortunately, he abandoned this combinational, synthetic approach when he dealt with the role of government. He observed: "Starting in the late 1950s price support levels were lowered, and by 1966 price supports for most commodities were at or below international prices. The market proved far superior to the government in finding new and profitable commercial markets for our farm products."

I must ask: By whom were price support levels lowered? Was it Adam Smith's "Invisible Hand" that did it, or was it the legislative branch of our government? The antithesis and dichotomy between "the market" and "the government" which Johnson has introduced into his analysis is particularly disturbing at a time when clamorous, demagogic voices denounce the government and seek to delude their audiences by implying that the role of government can be dispensed with in economic affairs.

Would it not be more fitting to discuss the respective roles of "the market" and of "the government" as complementary and to point out how we, as a political society, became more and more aware of international interdependence and learned how to adapt many of our agricultural commodity programs to world market realities?

International Trade and Agricultural Labor Markets: Discussion

Colin A. Carter

If there is any one central theme in these three papers, I believe it is one of the optimality of free, unrestricted trade in agricultural products and the importance of the export promotion of these products. It is interesting that I have been asked to discuss these papers since I am one of the coauthors of a recently published book on grain cartels, in which we take the view opposite to the central theme of the desirability of free trade (Schmitz et al.). We argue that restricted trade in certain agricultural products will increase the economic welfare of the United States and Canada.

Given the time constraint facing me, most of my discussion will focus on what I perceive as weaknesses in each of the papers rather than commenting on the strengths and contributions of each. I will discuss each paper in the order it was presented.

Trade in Products and International Migration in Seasonal Labor Markets

This paper by Emerson provides a framework for the discussion of the characteristics of agricultural labor markets for seasonal products. The premise of the paper is that alien farm workers are viewed by the United States as a problem, and the paper draws on basic trade theory to hypothesize that free trade in fresh fruits and vegetables could reduce the incentives for aliens migrating to the United States for harvest during the winter season.

The paper is organized into three major sections. A theory of agricultural labor markets is presented in the first section. The second presents a host of neoclassical trade theorems under a world of certainty, and the third hypothesizes how the theory of trade might be applied to the current migration of farm labor into the United States.

I find the model of the labor market (shown in Emerson's fig. 1) does not explicitly include the seasonality of supply and demand, and it does not incorporate the links between surplus and deficit labor regions. For these links to be in place, the demand for harvest labor (D_h) and the supply schedule for local harvest labor (S_1) in panel b of his figure 1 should be related to the supply and demand schedules in panel a. Seasonal incentives for labor migration are not explained by this model, even though the author indicates they are. The demand and supply curves would not only shift with the seasons, but the slopes would also change from season to season. The model, as presented, should also explicitly explain the differences in the equilibrium wages in the full-time and seasonal markets.

The third part of the paper puts forth two interesting hypotheses. These are, namely, that (*a*) free trade in fresh fruits and vegetables should lead to less labor migration to the United States during the winter, and (*b*) free trade could lead to increased labor migration to the United States during the summer. It would have been interesting had the author tested these hypotheses.

If Emerson had pursued these points, we would have learned more of the (*a*) current trade impediments in fresh fruits and vegetables, (*b*) the "dumping" lawsuit brought against Mexican producers by Florida producers in 1980, and (*c*) the question of the availability of adequate land and water in Mexico.

To conclude, I feel the author could strengthen this paper significantly by elaborating his model of the seasonality of the farm labor market and by pursuing an empirical investigation of the interesting testable hypotheses appearing in the paper.

Employment Implications of Exporting Processed U.S. Agricultural Products

I cannot disagree with Blanford and Boisvert when they state that too much interest in the recent growth of agricultural exports has fo-

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cused on the enhanced balance of payments and farm incomes and has neglected more general equilibrium effects on the U.S. economy. However, I do not believe that the authors have adequately addressed the broader questions we are interested in.

The paper begins by presenting a good historical analysis of primary versus processed agricultural exports. It then proceeds to discuss the nature and allocation of the U.S. expenditure on foreign market development, and it estimates the employment contribution of major categories of processed exports.

A major drawback of the empirical analysis is the small country assumption for the United States. With an expansion of U.S. exports, Blandford and Boisvert compute the marginal impact on domestic employment without accounting for the offsetting effect an increase in exports would have on the price of the product and competing products.

When the demand side of the international market is included, the scenario presented by the authors changes, and an argument can be made for the United States to restrict agricultural trade *vis-à-vis* the free trade situation, in order to maximize welfare.

Blandford and Boisvert should recognize the trade policies of the importing nations. Most of the major importers restrict trade in some of the products we are talking of, and it can be demonstrated that because of their dominant market position they are not only earning economic rents (Carter and Schmitz) but also may be the major beneficiaries of the production and export promotion subsidies in the United States (Sampson and Snape).

In conclusion, there are many important forces that are likely to reduce the positive employment effect of increased exports estimated by Blandford and Boisvert.

International Trade and Agricultural Labor Markets: Farm Policy as Quasi-Adjustment Policy

The paper by Gale Johnson is an interesting analysis of differences in product prices in major industrial countries and consequent impacts on resource prices and employment. He compares and contrasts the effects of the agricultural and trade policies of the European Community, Japan, Canada, and the United States and finds that in the United States agricultural resource adjustment has occurred even though the real price of farm products has been declining at approximately 1% annually. The growth of agricultural exports in the 1970s was not found to have influenced the adjustment process significantly.

Within the countries analyzed, the author assumes the most important objective of agricultural policy is to increase the incomes of the farm population. Nowhere in the paper does he make direct farm income comparisons, however. Instead, various proxy variables are used for income which are imperfect substitutes. The author investigates changes in farm employment and changes in the number of farms but does not compare farm returns in the European Community, Japan, Canada, and the United States. This omission weakens the informal testing of the propositions presented in the paper.

With the aid of the data in his tables 1–3, the author argues that the high product prices in the European Community and Japan do not significantly slow down the outflow of labor from agriculture. However, he does find off-farm employment is not as important to European farmers as it is in North America. To me this is not so surprising; and it indicates a slower migration from agriculture in Europe, as the author himself states that off-farm employment is one form of migration.

The author concludes there is no evidence of higher product prices in the European Community and Japan being reflected in higher returns to labor. Based on the analysis he presents, I find this conclusion to be too strong. The major reasons I question the strength of these conclusions are: (*a*) he is comparing relative changes in farm sizes instead of absolute changes; (*b*) no data on farm incomes are presented; and (*c*) there is some evidence of fewer farmers in Europe seeking off-farm employment.

I would like to conclude my comments on this paper with yet an additional puzzle. If the returns to labor from farming in the European Community are no higher than in North America, then why does a North American farmer have to farm at least ten times as much land as the European and therefore work harder in order to earn a comparable income?

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Empirical Estimation and Use of Risk Preferences
(Vernon Eidman, University of Minnesota, Presiding)

An Appraisal of Expected Utility Hypothesis Tests Constructed from Responses to Hypothetical Questions and Experimental Choices

Lindon J. Robison

A decision problem exists when the possible consequences of a decision are important and the best choice is not obvious (Anderson, Dillon, Hardaker). Moreover, when the consequences of each choice are described in probabilistic terms, the decision problem is said to exist under uncertainty. The expected utility hypothesis (EUH) characterizes the following solution for an uncertain decision problem: (*a*) identify the action choices available—$a_1, \ldots, a_n$ and the possible states of nature $\Theta_1, \ldots, \Theta_m$ under which action choice consequences may be experienced; (*b*) assign probability weights to the states of nature $P(\Theta_1), \ldots, P(\Theta_m)$ consistent with the probability calculus; (*c*) identify the consequence of the *i*th action choice under each *j*th possible state of nature (c_{ij}) and assign to each a preference measure, a utility value $U(c_{ij})$; (*d*) calculate the expected utility index for each action choice; and (*e*) implement the action choice with the highest index.

If expected utility indices are to correctly order action choices for an individual, several conditions must be met. First, the axioms underlying the EUH must be valid. Second, the preference measure $U(c_{ij})$ assigned to outcomes c_{ij} must accurately reflect the preference orderings of the individual. If preferences are determined by responses to hypothetical questions, the respondent must be motivated to reveal his actual preferences in the interview. Third, the choice set must be described accurately; that is, states of nature and their associated probabilities must correspond to subjective beliefs held by the decision maker. If any of the above conditions are not met, the EUH may fail to predict the decision maker's preferred action choice.

This paper will review several studies which have applied the EUH to practical decision problems. The success of these studies has been mixed. In all cases, they have been conducted as though the EUH were a confirmed hypothesis, or that decision makers behave as though it were true. It seems appropriate to stop and examine whether or not what we have assumed to be true can be justified legitimately. We propose to review selected studies which test the validity of the EUH in order to examine if the implicit confidence in the EUH is warranted. So it is important we begin with a description of what is required for a test of a theoretical hypothesis.

Constructing a Test of the Expected Utility Hypothesis

According to Giere, support for a theoretical hypothesis requires an experiment or set of observations which involve the hypothesis, initial conditions, auxiliary assumptions, and a prediction. For the theoretical hypothesis to be supported, two conditions must be met: (*a*), or condition one, if the auxiliary assumptions, initial conditions, and hypothesis are true, then a correct prediction will probably follow; and (*b*), or condition two, if the auxiliary assumptions and initial conditions

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are true and the hypothesis is not true, then the correct prediction will probably not be observed.

The word "probably" in the two conditions identifies the theoretical hypothesis as probabilistic rather than deterministic. This implies we do not expect perfect prediction, only that the evidence does not permit a rejection of the model—since truth of the model itself cannot be established.

Condition one requires an experiment involving the initial conditions, auxiliary assumptions, and hypothesis, which make a prediction. The experiment's prediction is then compared with actual outcomes to determine if condition one is satisfied. To satisfy the second condition the experiment's result must have a low probability of being predicted from an alternative hypothesis. If the same prediction results from many alternative hypotheses, the second condition would not be satisfied and the theoretical hypothesis not fully supported.

Suppose we wish to examine the support for the theoretical hypothesis that decision makers order action choices according to the expected utility hypothesis. The hypothesis in such a test is the EUH. The initial conditions are the choice set with consequences described in probabilistic terms and the decision maker's utility function. The auxiliary assumptions are (*a*) that the decision maker's utility function and the probability density functions describing the consequences of the action choices are measured accurately and (*b*) that the axioms underlying the EUH are valid. Alternative theoretical hypotheses might be that decision makers order choices based on (*a*) expected profits, (*b*) safety levels of income, (*c*) lexicographic utility functions, or (*d*) expected losses. Finally, the prediction is the action choice selected by maximizing expected utility. Condition one requires that the prediction matches the decision maker's actual choice. Failure to predict the actual choice forces a rejection of either the hypothesis, initial conditions, or auxiliary assumptions. Obtaining the prediction from an alternative model causes the EUH model to fail condition two.

Describing the Choice Sets

To examine support for the EUH, two choice sets are required. One set is used to obtain the decision maker's utility function. From the second set, an expected utility-maximizing choice is predicted which is compared with the decision maker's actual choice.

At least two approaches can be used to construct choice sets. One approach is to describe the actual choice set facing an individual. This method is referred to as the actual economic behavior approach. For complex choice sets, however, the actual economic behavior approach is difficult and costly and therefore rarely used. As a result, researchers more often construct artificial choice sets. This approach is referred to as the experimental approach.[1] The experimental approach has been criticized because it forces the decision maker to respond to hypothetical questions. If the decision maker is an expected utility maximizer over all his resources, including his time, he may respond to hypothetical questions in such a way that minimize his cost (time) of participating rather than reflecting his preferences for the hypothetical outcomes.

To overcome this criticism a third approach can be used. This approach, also an experimental one, satisfies the initial conditions by artificially constructing a choice set using significant outcomes and is referred to in this paper as the experimental approach with significant outcomes. The limitation of such an approach, of course, is that not all experiments can afford to reward respondents with significant outcomes. The exceptions would be in developing countries where significant outcomes may be small levels of incomes relative to that of the researchers.

Identifying the Decision Maker's Utility Function

The remaining initial condition to be satisfied before proceeding with a test of the EUH is to identify the decision maker's utility function. Identifying the decision maker's utility function, however, requires that he be confronted with alternative action choices so that indifference can be established between alternative uncertain action choices or between a sure outcome and an uncertain action choice. Efforts to derive a decision maker's utility function have almost always relied on the experimental approach for defining the choice set, asking the decision maker to choose between hypothetical choices.

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[1] This definition of the experimental approach differs from Binswanger's. His definition of the experimental approach is described in this paper as the experimental approach with significant outcomes.

Several studies have assumed that decision makers' utility functions belong to a certain family of functions, usually ones that are described by a single parameter. Then, defining choice sets using either the experimental or actual economic behavior approach, use the actual choice of the decision maker to solve for the parameter which identifies risk preferences. Example of such an approach can be found in Brink and McCarl, Binswanger, and Dillon and Scandizzo, who all used an equilibrium slope on an EV set or an equivalent mean-variance trade-off measure; Binswanger, and Grisley and Kellogg, who used partial risk-aversion measures obtained for a specific gamble; and Dillon and Scandizzo, who used single parameters from an assumed quadratic or power utility function.

While this approach may provide useful information about the distribution of risk coefficients measured, the reliability of these coefficients in predicting expected utility-maximizing choices needs to be established. And, until there is evidence to support the assumption that risk preferences can be described with single parameters, the results of this type of study cannot be used to evaluate the support for the EUH.

The difficulty of meeting initial conditions aside, there have been satisfactory studies made of the EUH. They are organized according to how the choice set was obtained. A separate class of studies reviewed examines the validity of the axioms from which the EUH is deduced. In the first study reviewed, the application of Giere's conditions is carefully considered. Of the remaining studies, because of space constraints, there is less mention made of Giere's two conditions.

Actual Economic Behavior Tests

Lin, Dean, and Moore constructed a comprehensive test of the EUH using the actual economic behavior approach to evaluate risk preferences on large-scale California farms. To describe the choices facing decision makers, the authors constructed an expected value-variance (EV) efficient set for six farmers in the San Joaquin Valley. Utility functions using the experimental approach were obtained and predictions about farm organizations made for each decision maker. The predictions resulted from maximizing expected utility for each decision maker over their respective choice sets. The test consisted of comparing the predictions with observed economic behavior. Condition two was satisfied by making predictions using expected profit and lexicographic models.

In only three of the six cases did the EUH model predict better than a lexicographic model or an expected profit-maximizing model. In none of the cases did the EUH model predict the actual farm plan followed by the decision maker. In fact, it would have been impossible for the EUH predictions to have made correct choices because the actual choices were not members of the choice set from which the predictions were selected. Thus, an important initial condition required for the test—correct identification of the choice set—was violated.

The authors then reconstructed the experiment and modified the initial conditions, restricting the decision makers' action choices to members of the EV set. In this approach, the authors adopt the experimental approach to define the choice set from which predictions are made. In the new test, the predictions matched the actual choices for three of the decision makers and came closer in the other three cases than the predictions from either the lexicographic model or the expected profit model. These results support the EUH.[2]

The Lin, Dean, and Moore study is appealing because both conditions one and two were used in the test. To meet condition one, an experiment produced a test which followed from the EUH, initial conditions and auxiliary assumptions. Then condition two was examined to see if correct predictions could be obtained from alternative hypotheses. But as an application of the actual economic behavior approach, it failed to satisfy the auxiliary assumption that the choice set was accurately described because actual choices were not predicted nor included in the choice set. Brink and McCarl experienced similar difficulty in their attempts to model actual economic choices using the equivalent of a mean-variance set. This evidence suggests that, except in very simple decision environments, constructing a test of the EUH using actual economic behavior will be difficult.

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[2] Even stronger support for the EUH is implied by Lin and Chang. They increase the number of correct choices using the EUH model by estimating preferences using a more flexible econometric model to describe utility functions.

A quite different lesson was learned from a test of the EUH made by Haneman and Farnsworth. They used the EUH model to test whether or not the EUH model could explain why one group of farmers adopted integrated pest management strategies (IPM) while another group continued with conventional (chemical) control programs. Using the experimental approach, they derive utility functions for both groups. They found no significant difference in the risk attitudes of the two groups; however, they did find significant difference in subjective expectations on yields and profits between the IPM and chemical control groups despite the fact that historically there was no significant difference.

Their study results showed that for thirty-five of the forty-four decision makers, either expected utility maximization or expected profit maximization predicted the pest control method actually being followed. And in five of the nine cases in which switching control strategies was recommended, the subjective probability density functions gave unclear preference signals.

While Haneman and Farnsworth produced a prediction consistent with the EUH and met condition one, their test failed to meet condition two because the same prediction was made by either the EUH model or the expected profit model. This evidence is weak support or lack of support for the EUH. Haneman and Farnsworth, however, infer something else. They infer that "subjective perceptions of outcomes rather than the type of choice criteria or the nature of risk preferences explain [the prediction]" [p. 19]. The confirmation of this hypothesis, however, requires more testing.

The Experimental Method Approach

In contrast to the lack of tests using the observed economic behavior approach, the EUH has been rigorously tested in an experimental setting, and the experiments and tests have been generally well constructed. A landmark in this class of studies was Officer and Halter's work with Australian wool producers. In this study and similar ones, the focus was on the auxiliary hypothesis: can we in fact measure accurately a decision maker's utility function?

The von Neumann-Morgenstern model for obtaining utility functions does so by finding a decision maker's point of indifference between the payoff associated with a gamble and a sure outcome. This method of eliciting preferences has been criticized (Young et al.) because (*a*) the act of gambling itself may have utility or disutility to the decision maker, and (*b*) the decision maker may have preference for particular probabilities. Including these two hypotheses results in a model somewhat different than the EUH model. The EUH model proposed that decision makers maximize the expected utility of wealth plus income. Letting U represent the utility function and income plus wealth be w, the EUH recommends:

$$\text{maximize } E[U(w)], \tag{1}$$

where E stands for the expectations operator evaluated over all possible action choices. What Officer and Halter suggest is that a better model might be either

$$\text{maximize} \quad E\{U[w, f(w)]\} \tag{2}$$

(the modified von Neumann-Morgenstern model), or

$$\text{maximize } E\{U[w,g,f,(w)]\} \tag{3}$$

(the Ramsey model), where g represents a perceived level of gambling and $f(w)$ represents particular probability levels associated with each income plus wealth level. Lacking a theory that explicitly incorporates g and $f(w)$ into the decision model, Officer and Halter hold them constant and examine predictions from models (1), (2), and (3). The predictions from models (2) and (3) are then compared with predictions using the model described in equation (1).

To conduct the experiment, the authors needed a choice set separate from the one used to measure preferences. Like Lin, Dean, and Moore they constructed one equal to an EV choice set. The members of the choice set consisted of alternative fodder reserves, a decision problem which was familiar to the decision makers. In this they avoided a criticism of later tests that the choice set was unrealistic and therefore not of interest to the participants.

Using carefully measured utility functions described in equations (1), (2), and (3), predictions from thirteen possible fodder reserve choices were obtained. The first test was to compare these predictions with actual choices made. And since the choices were restricted to the EV set, the conditions for the test were met. The second test was to compare predictions from alternative hypotheses; these were that decision makers select action choices on the basis of minimum expected cost, model (1), model (2), or model (3). The result was that the Ramsey model, model (3), gave accurate prediction 76% of the time and was superior to both models (1) and (2). The criterion of minimizing expected cost gave accurate predictions only 58% of the time. Moreover, the authors found that after reconsideration and reapplication of models (2) and (3) their accuracy improved. But before reconsideration, expected cost minimization performed better than model (2), and always better than model (1).

The evidence supports rejection of the naive EUH model. Without attention to decision makers' attitudes towards gambling and probabilities, the model does not predict any better than naive competitors like minimum expected cost models.

There is, however, a disturbing feature of the Officer and Halter study and later ones that use the Ramsey model to predict preferences. If utility of wealth is not independent of probability measures, then applying the EUH would produce unbiased results only if the action choices are described by uniform probability density functions. Applying the EUH over generalized probability density functions would affect both the weighting of the utility as well as utility. This lack of independence between probabilities and income would bias the resulting expected utility measures. Not withstanding this bias, reasonably accurate predictions were obtained, demonstrating that as a practical tool the EUH cannot be rejected. The Officer and Halter study also suggests that the EUH may often fail to predict accurately because the auxiliary assumption of accurate utility measurement was not satisfied.

Still the question remains, can the experimental approach based on responses to hypothetical questions be reliably used to obtain utility functions or to test the predictive ability of the EUH? Binswanger's study provided some answers. Before participating in gambles with significant outcomes, he found that decision makers demonstrated either more or less risk aversion than when they played an actual game with significant outcomes. Once having participated in the gambling experiment with significant outcomes, though, there was no statistically significant outcomes.

This result demonstrates that learning does occur in an experiment with significant outcomes. A question which remains is whether or not the experience with actual outcomes is required for the learning experience. Officer and Halter and Webster also observed learning without exposing the respondents to actual outcomes. Probably the most famous learning experiences reported in the literature was by Savage, who agreed to alter his action choice when confronted with evidence he had violated the independence axiom of the EUH.

At issue still is that after the learning occurs, do the learned responses to gambles more nearly match actual choices? And is there a similar learning curve which alters actual responses to economic choices if the choices are made repeatedly? More studies like Binswanger's are required to answer such questions.

Returning to the number of arguments in a utility function question, King and Robison assumed that decision makers maximize an expected utility model with arguments: income + wealth, and unknown arguments, $X_1, \ldots, X_n$, which may or may not be held constant. They argued that decision makers:

(4) maximize $E[U(y, X_1, \ldots, X_n)]$.

Arguments X_1 through X_n are not measured. The model instead measures

(5) $E[U(y, \epsilon)]$,

where ϵ is an error term resulting from failure to hold constant or measure variables $X_1, \ldots, X_n$. This approach suggests that decision theorists are naive to believe a single valued-single argument utility function can capture all of the information that is needed to predict preferences, or that they can predict a single preferred choice from a choice set with perfect accuracy while accounting for only one argument in the utility function. Using an efficiency criterion developed by Meyer which is consistent with the EUH, King and Robison measure an interval around risk preferences, where risk preferences are measured according to Pratt-Arrow absolute risk aversion function. Recognizing their measurements are only accurate in terms of quantifiable probability measures, they offer a somewhat unique approach toward risk measurement. First they identify as a Type I error the rejection of preferred choice from a choice set and as a Type II error the failure to order pairwise comparisons of action choices. Since the EUH with a single valued utility function discriminates on the basis of any absolute difference, it has the greatest likelihood of committing a Type I error and a small chance of committing a Type II error. That is, given any choice set it will select only one choice; the probability that this may not be the preferred choice is the likelihood of a Type I error. On the other hand, all pairwise choices will be ordered so that the probability of a Type II error is nearly zero. Efficiency criteria such as first- and second-degree stochastic dominance have a lower likelihood of producing Type I error but may result in large Type II errors because of their failure to distinguish preferences.

The authors propose an alternative, an interval that allows a trade-off between Type I and Type II error. The interval that King and Robison measure can be of any width or shape. The larger the width, the larger will be the Type II error and the smaller the Type I error. While the interval procedure has the potential to avoid many of the problems of discovering a utility measure consistent with the preference orderings of individuals, its ability to do so effectively is related to the width of the interval. And, methods for determining the optimal width are not fully developed at this time. Finally, it is much easier to apply since it only requires an ordering of action choices, not the discovery of indifference points.

To test Giere's condition one using the interval approach, three questionnaires were administered to a group of graduate students in agricultural economics. The first questionnaire measured risk intervals of different widths at different income levels. The second questionnaire derived utility functions using the modified von Neumann-Morgenstern model with neutral probabilities. The third questionnaire presented decision makers with a series of choices between pairs of distributions. The experiment required that the risk interval measures and the utility functions predict actual choices in each case; the test was the comparison of the predicted choices with the actual.

In this study, the EUH model predicted correct choices 65% of the time, or a 35% Type I error. This evidence, alone, is a marginal pass of Giere's condition one; but it ordered choices 100% of the time for a zero Type II error. The largest interval predicted correct choices (i.e., did not reject the preferred choice) 98% of the time, while the smallest interval predicted correct choices 72%, or a 2% and a 28% Type I error, respectively. The largest interval meanwhile ordered choices 9% of the time, and the smallest interval ordered them 91% of the time for Type II errors of 91% and 9%, respectively.

The conclusion from the King and Robison study is that the EUH is a useful, but not a perfect, predictive tool. Also, their study points to an important question: what is the optimal trade-off between Type I and Type II errors and what factors affect this optimal trade-off? More discriminating models will likely come at a cost of increased Type I errors. Less discriminating models will increase Type II errors.

Experimental Approach with Significant Outcomes

Two studies have been reported recently using the experimental method with significant outcomes approach (Binswanger, and Grisley and Kellogg). Both studies were similar in that they constructed an artifical choice set using significant outcomes and measured risk aversion using a partial risk aversion measure (Zeckhauser and Keeler, Menezes and Hanson). Both studies found a distribution of risk aversion measures. While much useful information was obtained in these studies, it is disappointing that no test evidence of the EUH was produced. To have conducted a test of Giere's condition one would have required an additional choice set be constructed, different from the first. Could they, for example, have derived utility functions using significant outcomes and then used these to predict actual economic choice? Perhaps a future study could follow such an approach.

Examining the Axioms

A different approach towards testing the EUH is to examine the axioms that define rational behavior and ask, do these conform to observed behavior? The answer that can be readily given is, no they do not conform, at least not all the time. Consider some of the evidence.

Tversky and Kahnemon, summarizing years of research, report consistent violations of the axioms underlying the EUH. In its place they propose a new theory—prospect theory. The first violation of the rational behavior axioms is what they refer to as the certainty effect, the overweighting of outcomes that are considered certain. The effect was first demonstrated by the French economist Allais (Allais and Hagen).

In this result, the authors only confirm what Officer and Halter, Webster, and Haneman and Farnsworth found—that probabilities deserve a place in the utility function. However, rather than attempting to hold the influence of probabilities constant, these authors propose an explicit form for its inclusion. Their proposed model is multiplicative; probabilities are weighted by a function v and outcomes by a utility function U. The resulting ordering index model can be written as,

$$\text{(6)} \qquad \text{maximize } E\{U(w)v[f(w)]\}.$$

Rather than proposing methods to measure the new function v, they suggest instead, that it is a standard function across individuals even though it is not well behaved at its end points. While this new model is intriguing it lacks two things, a method for measuring the function v and an experiment for testing conditions one and two. Nevertheless, its ability to explain what have been before aberrations of the EUH is encouraging.

Machina has also dealt with the Allais and related problems of EUH consistency. In contrast to the Kaneman and Tversky approach, Machina deduced a version of the EUH without the independence axiom. However, it leaves the EUH as it is now applied as only a local measure using a well-behaved function. Nevertheless, it does resolve many of the inconsistencies easily produced using the EUH.

Another assault on the axioms of rationality underlying the EUH was made by Janis and Mann. They quote John F. Kennedy who asked: "How could I have been so stupid?" after realizing how badly he had miscalculated when he approved the Bay of Pigs invasion (Janis and Mann, p. 657). The EUH portrays a carefully calculated expected utility maximizer weighing each possible alternative. And this is, in fact, how many decisions are made. But Janis and Mann argue that many other decisions are simply not made in this manner.

They describe five different coping models that describe decision makers' behavior depending on the stress level. (*a*) Unconflicted adherence: in this model the risks associated with maintaining the status quo are small and, as a result, the status quo is maintained. Subsistence farmers with well-established farming plans may exemplify such a decision model. There is no careful weighing of alternatives, only continued adherence. (*b*) Unconflicted change: in this model the risk associated with not changing is high, while the stress associated with changing is low. Perhaps this describes an environment in which past practices have failed. In this model, the action choice selected is the one most salient or the one most highly recommended. Again, there is no weighing of the alternatives, only unconflicted change. (*c*) Defensive avoidance: the model is characterized by high levels of stress. The decision maker's approach is to shift responsibility, procrastinate, and to remain selectively inattentive to correct information. Because the decision maker does not believe a better solution is available, he fails to examine completely the available alternatives. (*d*) Hypervigilance (panic): again characterized by high stress levels, the decision maker seizes on hastily contrived solutions, overlooking the full set of consequences because of his excitement. Again, the decision maker fails to act like the EUH rational man. (*e*) Vigilance: this model is characterized by moderate stress levels. The decision maker carefully assimilates and weighs the information and appraises each choice before making a decision. Only in this model would we expect to find operating our EUH rational man.

Janis and Mann offer no evidence their models meet Giere's condition one. Instead, they emphasize that while not all decision makers reflect the vigilance approach, they would be better off if they did. And the authors offer suggestions for improving the likelihood that the vigilance (EUH-like) approach will be used. The result is that one more argument probably needs to be added to our utility function—namely stress. A reasonable hypothesis, but one still in need of testing, is that high or low levels of stress may produce decision making behavior quite different from the rational EUH decision maker.

Conclusions and Recommendations

This paper concludes that there has been inadequate evaluation of the EUH. Nevertheless, based on what evidence is available, we can surmise the EUH is a useful, but far from perfect, predictor of choice behavior. Under experimental conditions, its Type I accuracy is in the neighborhood of 60% to 70%. The

EUH cannot be a perfect predictor based on a single argument because there are many other factors that influence the orderings of action choices. What is needed are studies which establish reliable confidence intervals to guide practitioners who use the EUH.

Instead there appears to have developed in the literature two classes of risk studies, both of which implicitly assume the EUH is a valid practical tool. The first class of studies is descriptive. These, summarized by Young et al. describe decision makers according to their degree of risk aversion, usually inferred from a single parameter measure. The second class of studies tries to correlate personal attributes with the parameters reflecting risk aversion (Halter and Mason, Binswanger, Whittaker and Winter, Grisley and Kellogg, and Dillon and Scandizzo). In neither class of studies has there been conclusive and consistent results produced. The only conclusion appears to be that risk attitudes differ.

In 1960, Halter and Beringer concluded: "Unfortunately, only a few empirical applications designed to test the predictive power of the [expected utility] index have been taken so far, and it is consequently difficult to appraise the reliability of the suggested hypothesis at this time" (p. 120). I suggest their statement still applies today, over twenty years later.

Because the EUH represents the most useful decision tool available, I suggest the research agenda in the future include answering the questions: (*a*) Are risk preferences intemporally stable? (*b*) What is the predictive power of the EUH *vis à vis* alternatives? (*c*) What is the role of learning in modifying the predictive power of the EUH? (*d*) What are the trade-off between Type I and Type II errors? It is also hoped that we avoid single parameter characterizations of risk attitudes, and instead focus on functional forms that reflect the fact that attitudes toward risk are described by a function rather than a parameter.

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Empirical Estimation and Use of Risk Preferences: An Appraisal of Estimation Methods That Use Actual Economic Decisions

Rulon D. Pope

The topic addressed in this paper concerns the conceptual basis, estimation procedures, and resources required for implementation of methods for estimating risk preferences by observing behavior. An attempt is made to review and appraise previous literature as well as to explore some alternative approaches.

To begin, it is important to contrast four general types of empirical settings of interest. These are micro (farm level), macro (market or other aggregations), descriptive (positivistic), and prescriptive (normative) studies. The prescriptive, or conditionally normative, studies seemingly have dominated agricultural economic studies of risk. These generally have been micro in nature and have focused on strategies to obtain risk efficiency for the firm. Very few empirical risk-responsive supply or demand studies have been both aggregate and normative in nature. This probably is because of a poorly developed literature on economic welfare under risk (e.g., see Grahm). The discussion here will touch on all four of the above approaches with a major focus on descriptive analyses of supply and factor demand of the firm or market.

Choice under Risk—Tests of Theory and Risk Preference Measurement

Many models of choice have been proposed as having prescriptive and/or descriptive relevance. The list is extensive and growing (see Kahneman and Tversky; Anderson, Dillon, Hardaker). By the very nature of things, normative economics seeks a synthesis of alternative models of choice. In the case of the theory of the firm, (expected) profit maximization seems to have dominated economic thought until two or three decades ago. However, with work of Von Neumann and Morgenstern and others, acceptance of expected utility, EU, maximization as the normative model of decision making under risk was well under way. However, this consonance was not without its detractors.

Expected Utility in the Laboratory

Some question whether maximization as a generally applied descriptive hypothesis is appropriate. Others focus on the issue of continuity and propose lexicographic orderings falling under the rubric of "safety first" theories (e.g., Moscardi and de Janvry). However, the most concerted criticism is broadly based and argues that the simplest of experiments show a uniformity of behavior at variance with EU maximization (Kahneman and Tversky, Heiner). Thus, the attack is basically on the descriptive relevance of the theory. The flavor of these arguments is given below because it seems that the principles involved not only impinge on so called "experimental or laboratory" risk aversion measurements, but must be cause for caution as one interprets "field" results on actual economic behavior of agricultural firms—which are discussed throughout this paper.

Various axiom sets which guarantee the existence of EU as a real valued function reflecting preference have been proposed, such as ordering and transitivity, continuity, and independence (e.g., Von Neumann and Morgenstern).

The most famous case of rather uniform violations of these axioms is the Allais paradox.

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Consider two problems, modified by Kahneman and Tversky (KT), from the original example of Allais:

Problem 1

	outcome	probability		outcome	probability
A:	\$25	.33	*B:*	\$24	1.00
	\$24	.66			
	\$ 0	.01			

Problem 2

	outcome	probability		outcome	probability
C:	\$25	.33	*D:*	\$24	.34
	\$ 0	.67		\$ 0	.66

The expected utility model yields $EU(1A) = .33U(25) + .66U(24)$; $EU(1B) = U(24)$; $EU(2C) = .33U(25)$; $EU(2D) = .34U(24)$, where U is utility and $U(0) = 0$.

KT report that a majority prefers B to A in problem 1, which implies that $.34U(24) > .33U(25)$. Further, a majority also chooses C over D, which implies that $.33U(25) > .34U(24)$. Hence, a contradiction arises. In a number of courses, I have found students to exhibit similar behavior, though with a lower percentage of inconsistencies than KT report, around 80%; perhaps repeated playing would eliminate these problems. In each case, the evidence against *EU* is based upon hypothetical lotteries or "laboratory" experiments as discussed by Robison earlier in this session. KT realize the shortcomings of this approach, as illustrated recently by Binswanger. Yet, it does seem clear that testing of *EU* versus other risk theories is appropriately done in this setting if the theory is meant to apply to an individual (see Diewert and Parkhan for tests of production theory under certainty).

Since much agricultural research is based upon the *EU* model, are there reasonable lines of defense for continued use of the approach in descriptive studies? Perhaps the most common rationalization is that *EU* is a useful rational normative model of individual behavior, but it describes only a representative decision maker (either a well-informed individual or some aggregate or average). This seems to be the tack taken when laboratory experiments contradict consumer demand axioms. Though the arguments by KT suggest further research on appropriate modelling of risk behavior, I will assume, for purposes of discussion and parsimony, an *EU* model since it still is predominant in economic analysis.

Expected Utility in the Field

There is an alternative form (than the laboratory approach) for testing theory based upon supply and demand functions which should be useful in pursuing further tests. It is well-traveled territory in much of riskless empirical economics (e.g., Appelbaum). One can deduce the differential restrictions of the theory and empirically test the implications of this theory using statistical tests (Wolgin's study is somewhat in this vein). There are many objections to this approach as well. It is argued that aggregation often destroys the empirical consequences of micro theory. Thus, tests of the theory based on aggregate data may be improper. (Risk analysis may be particularly vulnerable to aggregation.)

Finally, suppose one is not interested in testing theory but wishes merely to either measure risk preferences or measure response to risk. I would argue that it is still desirable to use a complete model of behavior in order to provide coherence so as to interpret fully the results of empirical work. These arguments are best developed by reviewing some of the deductive implications of the theory.

The Basic EU Model

The basic expected utility model might be described mathematically as $\max_{\mathbf{x}} E[U(w + \pi)]$, where E is expectation, U is utility, π is profit, w is initial nonrandom wealth, and $\mathbf{x}$ is a vector of control variables which may be constrained in some set.

When one considers a more explicit description of the above abstract problem, many issues surface. "Is the firm multiproduct?" "Are both price and production random?" "Do marketing or storage strategies affect production decisions?" Just to mention a few of them. It is apparent that affirmative answers are justified in most cases.

Consider first the simplest of characterizations, that of a single-product competitive firm where only output price is uncertain and where input decisions are made prior to the realization of price and hedging or storage is not available or prohibitively costly. Here,

$$\begin{aligned}\pi &= Pf(x) - \mathbf{r}'\mathbf{x} \\ &= (\bar{P} + e)\, y - \mathbf{r}'\mathbf{x},\end{aligned}$$

where $y = f(x)$ is the production function, $E(P) = \bar{P}$ and $E(e) = 0$, $\mathbf{r}'$ is a vector of input prices, and y is output.

The following implications have been obtained for the above model when there are two inputs (basically by Batra and Ullah):

(1) input demand curves slope downward under the following assumptions: The production function exhibits diminishing marginal products and production complementarity

$$(\partial^2 f/\partial x_i \partial x_j > 0,\ i \neq j); \tag{1a}$$

absolute risk aversion,

$$\psi(\pi) \equiv -\, U''/U', \tag{1b}$$

where $U'' = \partial^2 U/\partial \pi^2$, and $U' = \partial U/\partial \pi$, is nonincreasing ($\psi' \leq 0$);

(2) supply curves are upward sloping in expected price under nonincreasing absolute risk aversion;

(3) a mean preserving increase in risk (Sandmo) reduces output supplied under (1b) and reduces input demands under (1a–1b);

(4) inputs demands are less under risk aversion and (1a) than under risk neutrality ($\psi = 0$); and

(5) the expected utility-maximizing firm is a cost minimizer.

Using the approach of Silberberg, the following additional restrictions can be obtained (Chavas and Pope 1981b, Pope 1978b, 1980):

symmetry,

$$\frac{\partial y}{\partial r_i} + x_i \frac{\partial y}{w} = -\frac{\partial x_i}{\bar{P}} + y \frac{\partial x_i}{\partial w} \tag{6}$$

$$\frac{\partial x_i}{\partial r_j} + x_j \frac{\partial x_i}{\partial w} = \frac{\partial x_j}{\partial r_i} + x_i \frac{\partial x_j}{\partial w}; \tag{7}$$

(8) the matrix

$$\left\{\frac{\partial x_i}{\partial r_j} + \frac{\partial x_i}{\partial w} x_j\right\}$$

is negative definite;

$$\frac{\partial y}{\partial \bar{P}} - y \frac{\partial y}{\partial w} > 0, \tag{9}$$

$$\frac{\partial x_i}{\partial \bar{P}} + \sum_j \left(\frac{\partial x_i}{\partial r_j} \frac{\partial y}{\partial x_j}\right) + \frac{\partial x_i}{\partial w}\left(\sum_j \frac{\partial y}{\partial x_j} x_j - y\right) = 0, \tag{10}$$

where $i, j = 1, \ldots, N$ represent inputs and input prices.[1] The above Slutsky-type equations key on the impact of wealth on choices. It is easy to show that $\partial y/\partial w > (=)\ 0$ as absolute risk aversion is decreasing (constant). Further, $\partial x_i/\partial w = (\partial x_i/\partial y)(\partial y/\partial w)$, where x_i is the cost-minimizing input choice. It is seen that constant risk aversion implies that the wealth effects are zero. Thus, many implications under certainty are forthcoming:

$$\frac{\partial y}{\partial r_i} = -\frac{\partial x_i}{\partial \bar{P}}, \tag{11}$$

$$\frac{\partial x_i}{\partial r_j} = \frac{\partial x_j}{\partial r_i}, \tag{12}$$

$$\left(\frac{\partial x_i}{\partial r_j}\right) \text{ is negative definite,} \tag{13}$$

$$\frac{\partial y}{\partial \bar{P}} > 0. \tag{14}$$

There are, however, two restrictions which separate constant risk aversion from zero risk aversion or risk neutrality. These are:

(15) homogeneity of demand and supply functions does not follow from (10) except under risk neutrality (see [10], when $\partial x_i/\partial w = 0$, and $\partial y/\partial x_j = r_j/\bar{P}$); and
(16) input demands respond to changes in the distribution of P other than $\bar{P}$.

The above approach can be extended to add production uncertainty, futures markets, multiproducts, and other complexities. Further, multiperiod decisions and learning can be added, as in Epstein. Unfortunately, the qualitative conclusions reached above change considerably when one changes the risk specification.

However, the essential point above is that for any risk specification, differential type restrictions are implied on actual behavior. Given constant risk aversion, or some simple risk specification (e.g., mean-variance analysis), these are especially simple to work with. These may be used not only for testing but for interpretation of empirical results as well.

Empirical Studies of Risk Response

Two types of studies based upon some version of the above theoretical model are programming and econometric approaches. Most programming approaches are normative in nature and are in the activity analysis mode—based on either normality or a polynomial utility function. The most illustrative is the study by

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[1] Adding additional products does not really alter substantively (6)–(10). It will alter the qualitative conclusions regarding the sign of $\partial y/\partial w$ and $\partial x/\partial w$, except under constant risk aversion.

Lin, Dean, Moore. By comparing risk-neutral and experimentally derived risk-averse preference optima it was found that a continuous EU model predicted actual behavior better than the risk-neutral model. The work of Just (1975, 1974) is among the most well known of the econometric analyses of risk. These approaches are reviewed below.

Programming Models

Programming studies typically are based upon the Markowitz mean-variance efficiency problem:

$$(17)\qquad \begin{aligned} &\min v = x'\Sigma x,\\ &\text{subject to } \bar{\mathbf{R}}'x = e\\ &\mathbf{A}x \leq b, \end{aligned}$$

where Σ is an estimate of the covariance matrix of net returns (at unit level), $\bar{\mathbf{R}}$ is a vector of expected net returns, or $\bar{\mathbf{R}} = E(\mathbf{R})$, $\mathbf{A}$ is a matrix of technical coefficients with resource constraints b, and v, e are, respectively, total farm variance and expected returns. Solution of this problem yields a mean-variance portfolio conditional on e. As e is varied, an efficient set is generated, $e = g(v)$. The optimal farm plan is chosen by $\underset{e,v}{\text{Max}}\, EU = h(e,v)$, subject to $e = g(v)$. Several variants of (17) have been proposed, MOTAD being the most popular (Hazell).

When programming analysis is used for aggregate work, it is not possible to measure U experimentally. A possible approach is to assume

$$h(e,v) = e - (\lambda/2)v,$$

and estimate the risk aversion coefficient, λ, by minimizing some notion of distance of actual means and variances (or portfolios) from e, v, above, for a homogenous group of decision makers (Wiens and others).

A difficulty with this approach is that the remainder of the model must be measured properly: this includes $\mathbf{A}$, b, Σ, $\bar{\mathbf{R}}$. Small changes in any of these may substantially affect the estimate of λ. Perhaps a fruitful, but difficult, approach would be a more thorough blending of optimization theory and statistical decision theory. Least squares, Bayesian, or other procedures could be applied without specifying that all parameters ($\mathbf{A}$, b, Σ, $\bar{\mathbf{R}}$) other than λ are known with certainty.

This leads to a further point on some weaknesses of our current analyses. There is an issue which invariably is ignored in all of the programming studies: $\bar{\mathbf{R}}$, Σ are estimated from historical data (usually) and are subject to sampling error. This leads to a search for an appropriate estimator of $\bar{\mathbf{R}}$ and Σ. It also implies that the frontier may have almost no efficiency implications in the statistical sense. That is, frontier portfolios may be inefficient with large frequency. This problem has not received the attention it should by agricultural economists. (See Anderson, Klein et al., Jobson and Korkie for a discussion of some aspects of the problem.) Consider the estimation problem.

The Bayesian analysis is well resolved in principle: distributions should be estimated from sampled data and combined with prior information such that the optimal portfolio is obtained using the predictive distribution. In the classical case, it is less clear. Is a minimum variance unbiased estimator or its asymptotic counterpart desirable? Does one estimate EU given any arbitrary x level, or the efficient set of x's? In the latter case, unbiased or consistent estimation of the mean-variance frontier is difficult since $\hat{v} = \hat{x}'\hat{\Sigma}\hat{x}$, and x depends on $\hat{\bar{R}}$ and $\hat{\Sigma}$, where hats denote estimates (Jobson and Korkie). Given x and U, Meyer and Pope argue that an unbiased estimate of the probability density and expected utility is desirable.[2] The most commonly used procedures lead to biased estimates of expected utility. For example, unbiasedness implies that a normal distribution is estimated by a beta distribution. It can be shown that differences in estimation often will not alter the efficient risk-averse set but will alter choices among this set, for example, the placement of $g(v)$ will change.

To summarize, it would appear that further agricultural research should concentrate on these issues if risk response is to be adequately measured in programming models. It is even more relevant when using the models to make prescriptions: both estimation and testing are important issues which are largely unresolved.

Econometric Supply Response

A number of studies have generalized the Nerlovian type model to include risk terms (Just

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[2] Since EU merely ranks distributions, one wishes an estimator which reduces the risk of inappropriate ranking. This makes the estimation issue more difficult. A biased estimate of EU may "appropriately" rank distributions on average.

1974, Estes, Blakeslee, Mittelhammer; Adams, Menkhaus, Keith). Often these models seem to be based upon an activity analysis formulation with costs nonrandom (see [17]). Thus, a typical time-series linear formulation might be

$$(18) \quad x_t = \alpha_0 + \alpha'_1\bar{\mathbf{R}}_t + \alpha'_2\text{vec}(\Sigma_t) + \alpha'_3K_t,$$

where the α's are parameters to be estimated, vec (Σ) is a vector with all elements of Σ, Σ is the covariance matrix of gross revenue per unit level of the activity, and K represents other determinants of acreage.

Various schemes for the evolution of $\bar{\mathbf{R}}_t$ and Σ_t are specified, usually with an Almon, geometric, or fixed weight lag. Generally, $\bar{\mathbf{R}}_t$ and Σ_t are measured in nominal dollars. This leads one to worry about specification problems when gross revenue has a nominal trend of the inflationary variety. That is, $\text{var}(t\mathbf{R}) = t^2\Sigma$ and variance increases over time. Thus, one must be careful that acreage changes due to a smoothly changing variable other than risk are not interpreted incorrectly.

This can be amplified by considering $EU \approx w + x'\bar{\mathbf{R}} - (\lambda/2)\ x'\Sigma x$. It is seen that x at optimum is homogenous of degree zero in $\bar{\mathbf{R}}$ and Σ (this could be imposed on [18]). However, for a given λ, this implies that x responds to changes in the units of measurement (scale changes). This seems undesirable for most applications. Perhaps it would be preferable to impose homogeneity at the outset. For example, let

$$EU \approx (x'\bar{\mathbf{R}}) - (\lambda/2w) \cdot x'\Sigma x.$$

In this case, the optimal x would be invariant to common inflationary factors affecting profits and initial wealth since expected utility is defined over the ratio of net return to wealth or return an investment.

A second issue related to risk measurement concerns how perceptions of risk evolve. The adaptive framework is appealing, but it does ignore much of the difficulties in defining risk rationally as an extension of Muth, Wallis, and others. Perhaps the issue is best illustrated by assuming that the distribution is stationary in the sense that $\bar{\mathbf{R}}_t = \bar{\mathbf{R}}$ and $\Sigma_t = \Sigma$ for all t. Would one impose the adaptive structure on decision makers? From a Bayesian perspective the answer is yes, if these parameters are not known with certainty (Just 1974). Eventually, the decision maker would learn the values of Σ and $\bar{\mathbf{R}}$. In a non-Bayesian rational expectations model, it would appear that such would not necessarily be the case: expectations are formed from expected market changes conditional on available information. (This information includes the random draws on past error terms in the econometric market model. If the errors are correlated, they contain information useful for prediction as in Muth.) This would require more than acreage or supply equations in the modelling effort since presumably demand conditions are also important for the derivation of expectations. Thus, the requirements under this scheme are more burdensome.

However, there is a related aspect here that deserves mention. If there is no production uncertainty and if the decision maker discounts at the market rate, and marginal hedging costs are constant, production decisions depend only on the known futures price at the time of hedging (e.g., Holthausen). (This implication has nothing to do with the predictive accuracy of the spot price with the futures price.) This is a surprising result which leads one to the notion that price risk or any other risk should not affect acreage choice for crops where the mentioned assumptions are workable (see Gardner). However, when production is random, then deduction indicates that decisions will depend significantly on the distribution of spot price. Hence, research directed at the basis by which farmers make production decisions would be useful. Tests of the form, Ho: supply (acreage) responds only to future's price, Ha: supply (acreage) is as indicated in (18) and vice versa, should prove interesting.

Additional Approaches

This section discusses complete risk systems within the classical production function framework with input substitution. It ignores econometric portfolio analysis as in Lins, Gabriel, and Sonka.

Recent contributions in the journals using econometric systems production analysis has centered around three approaches:

(19) derive behavioral responses from an explicit specification of an objective;

(20) impose restrictions of the theory on an arbitrary reduced form (perhaps locally at a point);

(21) use duality notions to derive a behavioral system consistent with theory.

Examples of (19)–(21) under certainty are discussed in McFadden, Court and Woods, and Lau and Yotopolous. Note that under price uncertainty only, the firm is a cost minimizer and, hence, the cost function can be used advantageously in risk analysis. Questions involving elasticity of substitution can be answered using the cost function alone. Questions involving output effects can be analyzed by adding $\bar{P} = MC + MR$, where MC is marginal cost and MR is the marginal risk premium.

The merits of a systems approach are well known: not the least of which is the fact that a unique welfare measure exists if demands satisfy the theoretical restrictions (Pope, Chavas, Just; Chavas and Pope 1981b). It is clear from the brief review of empirical studies in the previous section that these studies lag substantially behind recent production studies under certainty (at least in scope). In fact, equation (18) corresponds to none of the above. As Just (1975) notes, one cannot even interpret the impacts of risk aversion when cost or production are random using this reduced-form approach. One is led to ask, Does risk complicate matters such that the approaches in (19–)(21) are infeasible?

There is no question that risk does complicate matters. However, as seen in equations (6)–(16), the approach in (20) is not too difficult to apply. Similarly, the dual approach is feasible but more difficult. Production uncertainty particularly makes these approaches cumbersome (Pope 1978a; Hallam, Just, Pope). This is so because EU becomes nonlinear in parameters—even in expected price under constant risk aversion.[3] However, at present, simple functional forms for the indirect expected utility function are not known which satisfy all of the needed theoretical restrictions that guarantee it as a valid utility indicator. A search of the restrictions implied by duality reveals the following. It can be shown that if there are N inputs and $M > N$ exogenous variables or parameters denoted by α, then the number of theoretical restrictions on econometric parameters (of the equality type) are $M(M - 1)/2$ symmetry restrictions, and if the matrix $\{\partial^2 EU/\partial\alpha\partial x\}$ is rank N, then there are $M - N$ nullity restrictions such as homogeneity of factor demands in certainty theory (see [10]). Additionally, there are restrictions implied by positive definiteness of various matrices (e.g., [8]). In the static certainty theory, $M = N + 1$: N input prices and 1 output price. Since risk multiplies $M - N$, it is clear that it requires more restrictions and a greater modelling burden.

In the author's opinion, use of (19) is the most obvious and the simplest way to proceed for many questions. For example, when

$$EU = \bar{P}f(x) - r'x - (\lambda/2)\, f^2(x)\, v(P),$$

where $v(P)$ is variance of price, the production system would be

$$S_j = \eta_j[1 - \lambda y v(P)/\bar{P}],$$

where S_j is the share $r_j x_j/\bar{P}y$, and η_j is the production elasticity. Risk aversion is tested treating λ as a parameter to be estimated with Ho: $\lambda = 0$, and $v(\bar{P})/\bar{P}$ estimated by a distributed lag. Notice that risk or risk aversion makes the estimating equation nonlinear in parameters even when η_j is linear in the inputs, x (such as a Cobb-Douglas or translog production function).

Space does not permit further discussion of this approach, but it is readily applied and has essentially the same data requirements as (18) on P but requires measures on the shares and output (see Pope 1978a for further discussion).

Conclusions

The basic thrust of this paper is that it is high time to do rather basic research in order to develop procedures for incorporating risk into the full range of production economic models and procedures. For some approaches, further work is required; while for others, obvious methods are workable (20). It seems that agricultural economists are likely to play an important role in further development of risk-response literature because of the importance of risk for descriptive work. Particularly in the area of production uncertainty, where general economists seem to have less interest, agricultural economists must do further work on developing pragmatic approaches to modelling choice. I see the development of these approaches as being in an embryonic state—similar to predual production-cost function developments and prior to the profit function approach (McFadden, Lau and Yotopolous, and Nerlove). It will take logical analysis, experimentation, and applications to develop an "established" method of anlysis.

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[3] It is interesting that many economic models happen to be linear in parameters, e.g., cost and profit. However, EU is not generally linear in parameters. This has crucial implications for the indirect expected utility function approach (Pope and Chavas, Chavas and Pope 1981a).

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Application of Risk Preference Estimates in Firm-Household and Agricultural Sector Models

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Agricultural production is generally a risky process, and considerable evidence exists to suggest that farmers behave in risk-averse ways. Neglect of risk-averse behavior in agricultural models can lead to important overstatements of the output levels of risky enterprises, to overly specialized cropping patterns, and to biased estimates of the supply elasticities of individual commodities. Other consequences may be overestimation of the value of important resources, such as land and irrigation water, and incorrect prediction of technology choices (Hazell et al.).

Recent years have seen rapid advances in the development of techniques for incorporating risk-averse behavior in agricultural decision models at the farm and sector levels. This paper reviews these developments and evaluates the possibilities of using empirical estimates of farmers' risk preferences in the construction of such models.

The most prolific advances have been made in the development of single period, optimization models for planning farm production under risk. These models are reviewed and placed within the context of the theory of the joint firm-household, which has recently spawned a number of econometric models of farm households. At the sector level, mathematical programming models provide the most explicit way of modelling aggregate risk behavior. But there is a growing literature on econometric supply models which embody some forms of risk behavior.

Static Models of Firm-Household Decisions

A family farm differs from most kinds of firms because part of the firm's output is consumed by the family itself. On small farms, this household dependency on the farm may effect the mix and level of crops and livestock produced, especially when alternative food supplies are expensive and unreliable.

Static theories of the equilibrium of family farms assume the existence of a one-period utility function for the household defined over the consumption of goods (including food) and leisure. It is assumed that the family maximizes this utility function subject to an income constraint. Income depends on farm output, which in turn depends on the amount of work (and hence leisure) undertaken, as well as on the allocation of land and other farm inputs. Income may also be supplemented by off-farm wage earnings where opportunities exist.

In a pure subsistence situation without trade in goods or labor, application of this model leads to a firm-household equilibrium in which the levels of production, leisure, and consumption are all simultaneously determined (Nakajima). Such models are inherently difficult to apply. The parameters of the utility function cannot be estimated in direct or indirect form, and it is difficult to estimate production and consumption systems simultaneously when these are nonlinear and inadequately identified. Nor is the model easily modified to take account of risk.

Most family farms are not isolated from all trading possibilities in goods and labor and tend to specialize to increase production while trading surplus goods and labor for goods providing greater utility. Under these circumstances, consumption and production decisions are less interdependent.

With perfectly competitive markets for labor and all relevant goods, the simultaneity between consumption, leisure, and production decisions breaks down completely (Lau et al.; Barnum and Squire, pp. 36–38). The firm-household equilibrium can then be derived

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from a two-stage decision process. First, the farm production problem is solved for maximum income (at least in the absence of risk), given that all labor is valued at the market wage. Second, given income and the market wage, the household's consumption of goods and leisure is determined.

This formulation has proved practical since indirect forms of the utility function can be derived in prices and income and can be estimated independently of the farm's production function. Recent work by Lau et al. has demonstrated the value of linear logarithmic expenditure systems and profit functions for these purposes. Barnum and Squire used a linear expenditure system and a Cobb-Douglas production function. Ahn, Singh, and Squire used a linear expenditure system in conjunction with a linear programming model of production to deal more adequately with a multiple crop situation.

All these studies ignore risk. Barnum and Squire (p. 39) note that if risk is introduced through an expected utility framework, then the separation of production and consumption decisions does not necessarily hold. If not, then this approach to estimating firm-household models breaks down. But if the separation holds, the production problem should involve the maximization of an expected utility function for income.

Single-Period Farm-Planning Models

A wide variety of optimization models now exists for solving production problems under risk, several of which are based on the maximization of expected utility. These models inherently assume that production and consumption decisions are separable. Also, when being applied to family farm situations in developing countries, attempts are usually made by the users to capture market imperfections. For example, constraints may be imposed on the amounts of labor that can be traded, and price differentials between the sale and purchase prices of farm-produced commodities may be introduced. Subsistence constraints are sometimes included, either in deterministic or chance-constraint form. Preferences for leisure are usually specified by charging a fixed reservation wage for family labor.

It is not clear whether these models are consistent with the firm-household equilibrium approach outlined above. But then most of these models were developed initially to analyze commercial farming situations in North America and Europe where income is virtually synonymous with consumption. In modifying these models for use in developing countries, more thought ought to be given to possible inconsistencies in the underlying behavioral assumptions, particularly when risk preferences are incorporated.

Freund first developed a farm production model incorporating risk aversion. He assumed an exponential utility function for income of the form $u = 1 - e^{-\beta y}$, where u denotes utility, y denotes income, and β is a risk-aversion parameter. Assuming that income is normally distributed, expected utility evaluates at $E(u) = E(y) - \frac{1}{2}\beta V(y)$, which is linear in the mean and variance of income. Freund maximized this function subject to a set of linear resource constraints using quadratic programming. In the absence of an estimate of β, he used a "reasonable" value for the North Carolina farm under study. Weins has since shown how the dual of the model can be used to impute a value for β using available data on factor prices and the farmers' observed cropping decisions.

A mean-variance (or E, V) model can also be justified assuming a quadratic utility function for income, regardless of the way in which income is distributed. In this case expected utility is linear in V, but quadratic in E (Markowitz p. 286). Using experimental techniques, Lin, Dean, and Moore elicited quadratic utility of income functions for six Californian farmers and used them to derive optimal E, V solutions for each farm.

A quadratic utility function is characterized by increasing absolute risk aversion and has been rejected as untenable by many theorists (Pratt). Yet there is little evidence to suggest that farm incomes are normally distributed, so Freund's E, V model may be of limited use.

The computational advantages of the E, V model must be offset against these difficulties. It can be solved by quadratic programming or by linear programming alternatives such as MOTAD (Hazell 1971). Utility functions with preferred theoretical properties often have expected values which are difficult to evaluate numerically, and higher order polynomials can lead to nonconvex programming problems.

The quadratic utility function also can provide an excellent second-order approximation to more desirable functions (Levy and Markowitz). When fitted to elicited utility-of-income data through regression analysis, it also appears to fit as well as most other functions (Officer and Halter).

Attempts to elicit individual farmers' risk preferences are expensive and time consuming. Furthermore, studies by Dillon and Scandizzo, Binswanger, and Moscardi and de Janvry suggest that individual utility functions may not be stable over time because they vary with the socioeconomic status of the household. It seems unlikely that direct elicitation will ever be a widely adopted approach in farm advisory work. A more practical approach has proved to be the derivation of a number of farm plans in the efficient *E*, *V* set, and to present these to the farmer for his choice.

The *E*, *V* approach is consistent with Tobin's separation theorem. If homogenous farmers face a choice between investing resources in a riskless investment or in the production of risky crops, then the separation theorem applies (Johnson). There will be an optimal mix of crops which should be grown by all the farmers, regardless of their risk preferences. But the optimal share of resources to be allocated to this crop mix as opposed to the riskless investment will vary with individual risk preferences. Optimal crop mixes could be determined for representative farms using *E*, *V* models, and these would then have widespread applications to other farms of the same type. Despite its promise, this approach has not been adopted, probably because few farmers face satisfactory riskless alternatives for the use of their resources.

Closely related to the *E*, *V* model is the mean-standard deviation (or E, σ) model. Since σ is the square root of V, then the efficient E, σ set of farm plans is identical to the efficient *E*, *V* set. Baumol has rationalized the expected gain-confidence limit decision criterion $E(u) = E - \phi\sigma$, where ϕ is a risk aversion parameter, which leads to linear indifference curves in the E, σ axes. If ϕ is known, then a unique farm plan can be selected.

The ϕ parameter can be estimated from direct elicitation of farmers' risk preferences. Using experimental methods, Dillon and Scandizzo obtained an average ϕ value of 0.9 for a sample of farmers in northeast Brazil. Moscardi and de Janvry imputed an average ϕ value of 1.12 for farmers in the Pueblo Project in Mexico. This value was derived from actual decision data and the first-order conditions for maximizing $E - \phi\sigma$ over an estimated production function.

One attractive feature of the $E - \phi\sigma$ model is that ϕ is a number with an intuitive interpretation. For example, if income is normally distributed, then a ϕ value of 1.65 would lead to the selection of the farm plan with the largest 5% income fractile. Such a level of risk aversion compares directly with the levels of risk tolerated by statisticians (or economists!) when performing one tail, 5% confidence tests on selected hypotheses. If Sir Ronald Fisher had a ϕ parameter of 1.65, should we expect rational farmers to be much different?

Several researchers have imputed values of ϕ by solving farm models for different values of ϕ, and selecting the value which leads to the closest fit between the actual and predicted farm plans. Various ways of measuring the closeness of fit have been used, such as the mean absolute deviation of the differences in crop areas. This method of estimating ϕ has been more common with sector models than with individual farm models. Hazell et al., Simmons and Pomareda, and Kutcher and Scandizzo have reported ϕ values ranging from 0.5 to 1.5 when derived in this way for aggregate models in Mexico and Brazil. Brink and McCarl recently reported ϕ values derived for individual farmers in the U.S. Corn Belt. They obtained values of less than 0.25 and concluded that risk preferences were not important.

There are two major problems with this approach to estimating ϕ. First, in using ϕ as a fine tuning device to validate the model, there is a real possibility that ϕ may be biased by model misspecification and data errors. Second, if farmers have access to risk-sharing institutions such as crop insurance or futures markets, then their farm-planning decisions will not reflect their real risk preferences. Unless these risk-sharing possibilities are included in the model, then ϕ is likely to be underestimated. This may explain the low ϕ values obtained by Brink and McCarl.

As a decision criterion, the E, σ model is subject to the same theoretical criticisms as the *E*, *V* approach. However, Tsiang has argued that the E, σ criterion is a good approximation to more desired decision criteria if the risk taken is "small" relative to the total wealth of the farmer. While this condition may easily be met for many commercial farms, it probably is not satisfied for small, subsistence farms in developing countries.

Although the E, V and E, σ decision criteria have been widely used for farm planning under risk, a variety of alternative approaches have been developed. (See Boussard 1979 for a recent review.) These decision models have typically been proposed on an ad hoc basis without much regard to their possible inconsistencies with the expected utility theory. They are usually justified on one or more of the following grounds: being computationally convenient (e.g., can be solved by linear programming); requiring less information on risky outcomes than the E, V and E, σ models; or having greater appeal to decision makers.

Game theoretic models require the least information about risky outcomes. They have a great deal of appeal for planning situations where few risk data are available and possibilities exist for disastrous outcomes. The minimax and maximin rules are also attractive because they do not depend on utility parameters for individual farmers.

A variety of safety-first models have also been developed. Some of these seek to minimize the probability $\propto$ with which income will fall below some critical level z. Others seek to maximize z, such that the probability of income falling below z is no larger than a given $\propto$. Still others seek to maximize expected income, or E, V utility, with income constrained not to fall below z with a probability greater than $\propto$. These models are closely related to the E, σ model, and require identical information on risky outcomes. Further, estimating values for the z or $\propto$ parameters is no easier than estimating parameters like ϕ.

Shackle's focus loss-focus gain decision criterion has been adapted in a class of models that are very similar to some safety-first approaches. Boussard and Petit first showed how focus-loss constraints could be included in linear programming models in which expected income is maximized. Webster and Kennedy subsequently developed a practical procedure for eliciting farmers' preferences between mean income and the focus-loss of income, and successfully applied this method to a number of Australian farmers.

Finally, in an attempt to remain within the framework of the expected utility theory but avoiding the need to elicit individual farmers' risk preferences, Anderson developed a Monte-Carlo simulation procedure (REMP) to select farm plans on the basis of stochastic dominance rules. This approach shows some promise, but it is limited by the relative computational inefficiencies of Monte-Carlo techniques compared to linear programming, and by the large number of risk efficient farm plans that typically remain in the efficient set, even when a third-degree stochastic dominance rule is used.

Turning now to risks in the constraint set, several methods have been proposed. Some of these methods, such as chance constrained programming, involve additional risk parameters (the acceptable probability levels of infeasibility) which have to be estimated. A difficulty arises in that the risk preferences expressed in the constraint set may be inconsistent with the risk preferences embodied in the model's objective function. An E, V model with a chance constraint cannot, for example, be derived from a single utility-maximizing model of the household.

Two approaches appear to be more satisfactory in this respect. Paris has shown how the E, V model can be generalized to take account of stochastic resource supplies. His method involves the formulation of a joint primal-dual model in which the risk in resource supplies enters the objective function as the variance of the dual prices. Similarly, Cocks has proposed a discrete stochastic programming model in which all the risks in the constraint set are collected as an additional monetary cost in the model's objective function. In both cases, no new information on risk preferences is required.

Agricultural Sector Models

Agricultural sector models can be characterized as containing equations for the supply and demand of important commodities which are used to provide market-clearing prices and quantities each period. The demand and supply equations can be estimated econometrically, and a suitable algorithm used to derive the market-clearing conditions. Or, the supply equations can be replaced by a mathematical programming description of production. Duloy and Norton have shown how linear programming models can be used to simultaneously solve the production and market-clearing problems.

Much work has been done on estimating demand functions for agricultural commodities, but these functions do not include risk-averse behavior on the part of consumers. Since consumers can usually defer purchasing decisions until after prices are known, it may be reasonable to assume that risk is not important.

A major difficulty in incorporating producers' risk behavior in sector supply models is the need to aggregate individual utility functions. This would not be troublesome if utility were measured in a cardinal way, but one of the strengths of the expected utility theory is that it is based on ordinal preference indices. These preference indices are only defined up to linear transformations, and cannot strictly be added over individuals. This restriction is more serious for some decision criteria than others. Quadratic utility functions for income cannot be added, so there is little point in eliciting parameters from individual farmers for these functions if the overall purpose is to build a sector model.

On the other hand, the β and ϕ parameters in the $E - \beta V$ and $E - \phi\sigma$ decision criteria are invariant to linear transformations in the underlying utility-of-income functions, since they are the slopes of the relevant indifference curves between E and V or σ. These parameters can be averaged over individuals, as in Dillon and Scandizzo. This property makes these two decision criteria particularly attractive for sector modelling.

Another consideration is the need to aggregate risk preferences in ways that ensure that the marginal cost of risk in the aggregate supply is equal to the sum of the marginal risk costs for individual producers. Interfarm covariances in prices and yields can affect aggregate measures of risk, and failure to remove these covariances will lead to biased estimates of aggregate supply response. In mathematical programming models inappropriate aggregation procedures will lead to production solutions that are optimally diversified across farms. Such solutions could only be implemented by government fiat, and would not be consistent with the assumptions of a competitive industry (Hazell and Scandizzo 1974).

To illustrate this aggregation problem, suppose all the farmers represented by the model adhere to an $E - \phi\sigma$ decision criterion. The relevant measure of risk at the aggregate level is then $\Phi\Gamma = \Sigma_i\phi_i\sigma_i$, where i denotes the ith farm, and Φ and Γ are, respectively, appropriate aggregates of ϕ_i and σ_i. If Γ is chosen as the aggregate risk variable $\Sigma_i\sigma_i$, then Φ must be defined as a weighted average of the individual farm risk parameters, where the weights are the risk shares $\sigma_i/\Sigma_i\sigma_i$.

Hazell and Scandizzo (1974) developed a linear programming method for solving agricultural sector models to obtain perfectly competitive levels of outputs and prices in all product markets when producers behave according to an $E - \beta V$ or $E - \phi\sigma$ decision criteria. Most applications of this method use the $E - \phi\sigma$ model, and the value of ϕ chosen is typically the value which gives the best fit between the model's predicted cropping pattern and the actual cropping pattern observed in some base period. For example, see Hazell et al., Simmons and Pomareda, Kutcher and Scandizzo.

Some of the problems of this approach to estimating ϕ have already been discussed, but when prices are endogenous to the model an additional complication arises. Hazell and Scandizzo (1977) have shown that alternative assumptions about the way in which farmers form their price and yield expectations lead to different market equilibria when production is risky, and these equilibria must be obtained from different sector model formulations. They developed sector models to obtain competitive market equilibria corresponding to farmers holding rational revenue expectations and to farmers forming independent forecasts about prices and yields. In applying these models, they obtained results which suggest that market equilibrium solutions corresponding to revenue expectations are more risk efficient for given levels of ϕ. Selection of a best fitting value of β or ϕ could therefore lead to quite different results depending on the kind of price and yield forecasting behavior assumed in the model. Without knowledge of how farmers actually form their expectations, then ϕ remains largely indeterminate.

Econometric models of aggregate supply which incorporate risk behavior are less well developed. Reutlinger developed a supply model in which farmers are assumed to plan on the basis of the game-theoretic minimax decision rule. More generally though, risk considerations are included in supply functions in an ad hoc way, and no attempt is made to derive these functions from underlying utility-maximizing behavior.

Just developed an adaptive expectations model in which supply is related to lagged expectations in both the mean and variance of past revenues. Applications of this model show that supply can be quite responsive to changes in the variance of revenues.

Dynamic Models

There are several examples of recursive linear programming models (for example, Day and Singh). These models assume that farmers plan one year at a time but that they place limits on the extent to which they are willing to adjust their cropping patterns each year. These limits are incorporated in the model as upper and lower bound constraints on the cropping activities and amongst other things, are assumed to represent a cautious response to risk. In practice, estimation of these bounds is entirely artibrary, and there is no apparent way to relate them to direct measurements on risk preferences.

Proper analysis of investment decisions and farm growth requires the construction of multiperiod models. These models greatly complicate the interdependencies between consumption, production, and leisure decisions for the farm household. Even with risk-neutral behavior, separation of these decisions requires the strong assumption of a perfect capital market.

Boussard (1971) has shown how these interdependencies can be incorporated into multiperiod linear programming models. He assumed that the consumption function is linear and maximized terminal wealth. But in introducing risk, Boussard chose to use focus-loss constraints because these do not directly affect the model's objective function.

Risk behavior is more easily introduced into multiperiod production models in which the discounted value of future income is maximized. If the probability distribution of discounted income can be calculated for each farm plan, then expected utility can be maximized instead (see chap. 8, Anderson, Dillon, Hardaker). With this formulation, measurements of single period utility functions can be used directly.

Conclusions

Several methods exist for incorporating risk behavior in farm and sector planning models. Unless incomes are normally distributed then few of these methods use decision criteria that can be derived from utility functions for income that have preferred theoretical properties. Nor has much attention been given to the conditions under which production decisions can be separated from household consumption and leisure decisions. But these methods are computationally efficient, and have proved useful in a wide range of applications.

Most methods require knowledge of one or more risk-preference parameters. There have been several attempts to elicit these parameters directly from individual farmers, and the E, V and E, σ models have been most extensively used for these purposes.

My own view is that direct elicitation of risk preferences is not likely to become a widespread approach. Pragmatic attempts to derive risk parameters from observed cropping patterns seem more promising, particularly if an $E - \phi\sigma$ decision criterion is assumed. In constructing sector models, there are also difficult aggregation problems which further weaken the value of risk parameters elicited for individual farmers.

These conclusions demonstrate the need for some new and innovative breakthroughs. I suspect these will have to come from econometric approaches to measuring risk parameters. But let us keep things in perspective. In my own applications of the $E - \phi\sigma$ model at the farm and sector levels, I have often had far less difficulty in choosing a reasonable value of ϕ than in obtaining basic data with which to estimate σ.

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Empirical Estimation and Use of Risk Preferences: Discussion

Hans P. Binswanger

In 1976 a number of people present today attended a conference in Mexico which has since then (1978) resulted in a state-of-the-arts volume edited by Roumasset, Boussard, and Singh on risk, uncertainty and agricultural development. The papers presented today convey the feeling that since that time there has been little progress in measuring risk aversion or in discriminating between alternative theories of behavior under risk. I will argue that this is because the papers concentrate on approaches to measurement of risk aversion and testing of theories which hold little promise of fast progress. Please excuse that I will be somewhat partisan in the remarks and rely heavily on studies with which I have been involved. I know them best.

Pope's paper expresses the view that structural models of factor demand and output supply behavior under risk will be helpful in the future to test alternative theories of behavior under risk with econometric procedures. The structural models also should be helpful in interpreting the coefficients of reduced forms (which incorporate some measure of production, price, or revenue risk) in terms of behavioral parameters such as risk aversion or in terms of technology parameters, rather than using them only for projection purposes. In 1976, I very much shared this view when summarizing the Mexico risk conference, but today I am much more skeptical. Research since then has uncovered a number of additional difficulties, all of which are discussed in one way or another in these three papers. In order to derive any testable implications of the type discussed in the last part of Pope's paper, one must make, explicitly or implicitly, assumptions about several matters.

(*a*) The nature of risk: Does risk derive only from prices or also from production and/or costs? What is the nature of the distributions of these risks?

(*b*) Utility: What are the arguments of the utility function and what is its form?

(*c*) Expectation: Do producers form expectations on prices and quantities separately or on revenues or profits directly? How many years is the length of lags involved in forming price and risk expectations?

(*d*) Risk diffusion: What are the opportunities in future markets, in insurance markets, and can credit markets be used to diffuse risks? What other mechanisms of risk diffusion do farmers have?

(*e*) Labor and output market opportunities: What are the costs of participating in the output market? What is the nature of demand in the labor market? Can production and consumption be modeled separately?

(*f*) Aggregation rules: How are individual behavioral rules to be aggregated into aggregate demand or supply functions?

It is of course possible to model explicitly and test alternative specifications in any given one of these areas, but there are so many different ways of maintaining some hypotheses while testing others that this is an arduous route. Moreover, we know from the literature on rational expectations (Eckstein) that many alternative specifications will lead to similar, or even identical, reduced forms; so that discrimination among alternatives will be exceedingly difficult, especially with single, short, time series.

Pope's paper recognizes these difficulties, especially in regard to alternative specifications of risks and of utility functions, but he glosses over the enormous problems which result from this for the structural econometric approaches.

Robison's paper first discussed the enormous difficulties encountered by previous researchers in using actual farming decisions to test the subjective expected utility (SEU) model. Such tests usually use programming approaches to describe behavior, the technology, and the nature of the risks. They en-

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counter all the problems of the econometric approaches: In order for the comparison of a predicted decision (i.e., a farm plan) with an actual one to constitute a test, the model must specify precisely all the elements (*a*)–(*e*) above. In addition, one must choose numerical magnitudes for all parameters of the technology and the behavioral relations.[1] These are even more exacting requirements than for the econometric approach to testing utility theory.

Given the difficulty faced when we test theories of behavior under risk and of measuring risk aversion with real-world decisions, how then should research proceed? Are experimental approaches capable of providing answers more quickly? Robison considers a few "experimental" studies in agriculture which are all based on hypothetical choices and mentions Kahneman and Tversky's very brief review of a rich experimental psychology literature aimed at testing the axioms of the SEU model. More complete reviews of that literature are available (Luce and Suppes, Grether, Grether and Plott), and I cannot hope to make up here for the lack of review in Robison's paper. Suffice it to say that this literature has its problems too; it often comes to inconclusive results, for example, on the existence, extent, and stability of probability preferences. On the other hand it appears frequently to reject the axiom of transitivity of individual preference orderings, even in tests with fairly substantial monetary rewards (Grether and Plott).

The advantage of experimental studies, of course, is that, rather than making assumptions about the features (*a*)–(*f*) above, one can design experiments where many of the features are under the control of the experimenter, and where it is therefore easier to focus on testing subsets of the assumptions of the theory than with alternative approaches.

I initiated experimental studies on risk aversion in India in 1977, in relative despair after colleagues and I had spent a full year trying to measure risk aversion with the Dillon-Scandizzo interview method but had failed to find replicable results.[2] Experiments were then carried out with significant and large outcomes. Similar experiments were carried out by Sillers in the Philippines, Grisley in Thailand, and Walker in El Salvador. Binswanger and Sillers give a brief comparative summary of the results so far achieved, which indicates the following:

(*a*) Farmers in developing countries are almost universally risk averse when confronted with prospects with significant outcomes. Both risk neutrality and extremes of risk aversion are rare. Thus, at high levels of payoffs most individuals exhibit intermediate or moderate risk aversion.

(*b*) At low payoffs a substantial proportion of individuals exhibit risk neutrality. But at low payoffs and/or in practice rounds, results can be quite noisy when conducted with small sample sizes.

(*c*) As payoffs rise, absolute risk aversion declines sharply, partial risk aversion rises slowly, and relative risk aversion decreases rather than increases, as Arrow had hypothesized (Binswanger 1981, Sillers).

(*d*) As wealth rises, partial risk aversion increases only modestly.

(*e*) When game formats simulate real losses, individuals are more risk averse than for games which result in no real losses. But the extent of extreme risk aversion does not rise in experiments with real losses (Sillers).

(*f*) The assumption of asset integration, whereby individuals evaluate new prospects in terms of their final impact on wealth states, has to be rejected (Binswanger 1981, Sillers).

(*g*) All safety-based models of behavior which make predictions about response patterns in the experiment are inconsistent with the observed experimental results. This includes safety-based models with and without income integration (the analogue of asset integration for utility theories) and lexicographic rules. Several safety based models fail to make any predictions whatsoever (Binswanger 1981).

(*h*) Sillers failed to find probability preferences in the only test carried out with farmers.

(*i*) Measured risk aversion coefficients have been shown to be related in the expected way to farmer investment decisions in regression analysis (Binswanger et al.).

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[1] Hazell implies that a risk aversion parameter can be estimated via programming models by selecting that parameter which results in cropping patterns close to observed ones. This is the case only if there are no specification errors anywhere in the model and if all parameters, except for risk aversion, have been correctly chosen. This is most unlikely ever to be the case.

[2] Hazell is concerned about the fact that risk aversion measures in Dillon and Scandizzo differ for individuals in different social classes. This is not worrisome, however, since every local measure of risk aversion on a utility function would differ according to wealth unless very restrictive utility functions are chosen. What worried me is not that feature but the lack of replicability of the measures for the same individuals over short periods of time.

The results are far clearer than for many experimental psychology studies. This, I believe, is accounted for by the fact that payoffs were significant and varied dramatically over the gain sequence (by a factor of up to 100).[3] Most testable propositions derive from the latter feature of the experiments.

There is no question in my mind that powerful tests of additional assumptions of existing or new theories of behavior under risk can be designed and parameters estimated. In particular, it is possible to design reward systems which will pay people according to how accurately they predict future events, such as prices, yields, or revenue. Thus, much of what is treated in econometrics as unobservable variables can be made observable in experiments. Hypotheses about expectation formation could then be tested with relatively simple multivariant methods using observed "unobservables."

Let me also dispel the notion that experimental costs are high. The Indian experiment could be repeated in the United States (with some new money savings features) for roughly $100,000 to $200,000 of prize money plus the costs of carrying out and analyzing the experiments, maybe another $100,000. Many research projects in economics nowadays cost as much or more, especially if the cost of the analyst's time is included in running endless regressions or building programming models. And alternative approaches will simply not provide the answers which we are seeking in the forseeable future.

Finally, it is important to realize that experiments cannot be expected to provide answers to all questions. Furthermore, the experimental psychology literature presents clear evidence that it is as easy to misspecify an experiment or misinterpret its results as for econometric or programming studies. Nevertheless, the casual treatment of experimental methods in the papers of this session and in the profession as a whole is unwarranted.

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[3] Experimental psychology research has most frequently asked hypothetical questions or given very small rewards for very many questions. I have not yet seen any studies incorporating variations in payoff scales.

Empirical Estimation and Use of Risk Preference: Discussion

Terry Roe

These remarks are directed at issues that came to mind when reading Hazell's paper, which arrived in time to allow for reading and thinking. My major focus is on the importance of obtaining insight into the agent's risk preferences and personal beliefs as to the likelihood of uncertain outcomes. I conclude with questions relating to modeling risk in sector and firm-household models.

Bernoulli's principle—or as it is otherwise known, the expected utility theorem—is a premise underlying much of the research on and models of decision making in a risky environment, an environment where an agent makes choices based on personal beliefs of the likelihood of uncertain outcomes. When decision making is viewed in this context, there are two related components that need emphasis. One involves the nature of an agent's preferences, which can be expressed as a cardinal (indirect) utility function. Hanoch and others have shown the restrictions on an agent's indifference map for goods and services that are implied by selected types of risk aversion. These restrictions are especially important when modeling risk behavior in sector-wide models with endogenous prices and when attempting to account for risk behavior in models of the firm household.

The second component involves the agent's personal beliefs about the occurrence of uncertain events. Bayes' theorem and the various forecasting models based on the theorem (Anderson and Moore) are often used to explain how agents update their beliefs. Psychological research on decision making under uncertainty has raised serious questions about this approach (Musser and Musser).

Within this context, it is my view that (*a*) considerable effort during the last several years has been expended to obtain insight into an agent's preferences, with findings that by and large suggest risk averseness; (*b*) while the conceptual literature on the formation of expectations is quite extensive and includes theories of rational and adaptive expectations (Sargent), few approaches have attempted to measure the influence of cognitive factors and information availability on the formulation of beliefs; and (*c*) little effort has been expended to measure empirically both the effect of an agent's preferences and beliefs on observed enterprise choices in the same problem setting.

Value to extension agents and policy makers lies in knowing the effect of both preferences and beliefs on agent choices. Knowledge of preferences provides insight into the demand for alternative ways to diversify or otherwise avoid risk. While risk preferences might to some degree be associated with age and education, policy instruments are not likely to have any direct effect on preferences. However, the second component, agents' beliefs, can be affected by market imperfections and are amenable to change by government intervention. The formulation of beliefs is a cognitive process. As such it can be influenced by formal education, experience, extension activities, and the contents and cost of information (a major market imperfection in LCDs) that serve to improve and reduce uncertainties in the means-ends, cause-effect calculus of the decision-making process. This influence can be viewed as a learning process where subjective expectations of uncertain events become increasingly more consistent with realizations.

Failure to account for both the preference and belief components of the problem can lead to specification bias in behavioral models. Risk specifications in optimization models, as Hazell points out, tend to yield results in closer agreement with observations than optimization models without risk specifications. However, the majority of these models have

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emphasized the risk preference component of the model specification problem relative to showing the consistency between the formulation of beliefs and the specification of risk indices. An exception includes the contributions cited by Hazell where risk behavior is specified in a model with endogenous prices. In this case, explicit statements are required on the process by which agents form their expectations. Other exceptions include Just; recently Pope (1981) has shown the effects on supply response of dispersed price expectations.

Empirical insight into these structural issues can be obtained through the direct elicitation of risk preferences and subjective probability distributions (Hogarth). While the insight obtained from the direct elicitation approaches can be valuable to either improving upon the specification of risk in optimization models or in providing insight into the direction of specification bias inherent in these models, I share Hazell's view that the direct elicitation of risk preferences is not likely to become a widespread approach. In addition to the problem mentioned by Pope and Hazell, it is my view that these approaches are costly in terms of the time and resources required to elicit preferences over any reasonable-size sample of agents. Further, if the elicitation process is based on a game situation or if agents are asked to choose among a set of risky prospects that either do not reflect or bear little relation to the risky prospects they perceive to face in their enterprise choices, then, in my view, it remains to be shown whether the behavior implied by the results of these methods is consistent with, or can otherwise explain, the choices agents actually make.

Econometric approaches where models are fit to data on observed behavior, in my view, show promise of obtaining insight into both the risk preference and belief components of the problem. Contributions in this area include Moscardi and de Janvry, Roe and Nygaard, and Pope (1978, 1980), who has shown the implications of expected utility theory on restrictions relevant to reduced form econometric models. Moscardi and de Janvry obtained estimates of farmers' risk preferences by substituting the level of input usage into estimates of expected marginal value product and factor cost, from which risk aversion coefficients were computed as a residual. One of the several problems with this approach is that the expected marginal values product is not the farmer's subjective estimate. Instead, estimates of the marginal product are obtained by regressing observed yield on input variables.

Roe and Nygaard, in a study of Tunisian farmers, and Tubpun, in the case of farmers in Thailand, have attempted to improve upon this approach by estimating, at the time of seed bed preparation, farmers' subjective forecasts of their expected harvest yields, conditional on the inputs they applied and expected to apply throughout the remainder of the growing season. Data on observed yields were also collected at harvest. In both studies the estimates of farmers' risk preferences, based on their subjective forecasts, appeared to yield more consistent results than the risk preference estimates derived from actual harvest yields. A comparison of farmers' yield forecasts with realized yields provided insight into the accuracy of their subjective beliefs. In the case of new seed varieties, farmers' choice of inputs tended to be influenced to a larger extent by their beliefs than by their risk preferences. These studies illustrate the usefulness of obtaining insight into both risk preferences and beliefs.

Pope's contribution is, in my opinion, an important step in the use of econometrics to obtain insight into the effects of preferences and beliefs on factor demand and product supply. The application of this approach to a restricted class of utility functions is not necessarily straightforward, however. For instance, Pope shows that the factor demand and supply equations implied by a class of utility functions have the moments of the distribution of the random variable as arguments. In principle, these moments are not observable if they are formed by the agents' cognitive process at the time input and output decisions are made. Hence, in my view, explicit hypotheses must be stated as to how agents formulate their expectations. These hypotheses will almost certainly add a dynamic dimension to the problem. In any case, these hypotheses may then be tested when the reduced form equations are fit to the data. This should provide insight into market performance, since welfare implications of market equilibrium under risk depend on how agents formulate their expectations.

Finally, the specification of risk-averse behavior in sector and firm household models raises questions of consistency that, in my view, need more attention than they have received, in spite of the computational advantages of E, V models. For instance, in the case of constant relative risk aversion, constant absolute risk aversion, and quadratic utility functions, the results of Hanoch and Stiglitz show that the level of risk aversion is not independent of price changes. Their results also indicate that the direct utility function is homothetic in the case of constant relative and constant absolute risk aversion. Under special circumstances, the direct utility function is also homothetic in the quadratic risk preference case. The first result raises the question of whether the risk aversion parameter (Hazell's β and ϕ) in optimization models with endogenous prices is invariant to price changes. If a second-order Taylor series approximation of the utility function is chosen, it seems to me that we still face the question of whether the approximation is independent of price changes. If the risk aversion parameter is not independent of price changes, then it is possible for a different value to exist for each optimal solution to the sector model.

In the case of firm-household models, Hazell pointed out that if risk is introduced through an expected utility framework, then separation of production and consumption decisions does not necessarily hold. Even if the conditions under which separation holds are stated, the use of an expected utility framework which implies one of the abovementioned types of risk aversion also will imply homothetic preferences. Homothetic preferences generally are not consistent with observations that, for low income agricultural households in LDCs, relative expenditure shares change as disposable household income increases.

In my opinion, we are only in the initial phase of distinguishing acceptable approaches to these problems and to obtaining insights into the economic welfare implications they imply.

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Books Reviewed

Bapna, S. L. ***Aggregate Supply Response of Crops in a Developing Region.*** **New Delhi, India: Sultan Chand & Sons, 1980, x + 164 pp., Rs 45.00.**

The analysis of aggregate supply response is a critical exercise for the policy-oriented economist interested in the developing world. S. L. Bapna has provided a worthwhile example of this research form. Using a time series of aggregate agricultural production from the Indian district of Ajmer, the author explores issues of acreage and yield response, the impact of weather on production, and the variable response of traditional and transitional agriculture. If this work had been done twenty years ago, it would have contributed greatly to the new thinking about developing farmers' rationality. The results today are not surprising, but they can play a role in evaluating policy for developing agricultures.

There are two main empirical findings: the elasticity of aggregate agricultural supply in the Ajmer region is about .24, with yield response accounting for more than 75% of the total; there is no significant difference in aggregate response between changing and traditional agriculture. Additional interesting information is given about the specification of rainfall and technology variables in supply equations.

Unfortunately, after deriving these results, Bapna devotes only a paragraph in the last chapter to their policy implications. At the profession's current level of understanding, the most interesting discussions should be about policy and not about the mechanics of supply analysis.

An additional drawback to the text is its style. It reads too much like a dissertation (on which it was based) with the obligatory definitions of elasticities and an entire chapter devoted to a chamber of commerce type description of Ajmer and its agriculture. On the positive side of this style issue, however, one finds complete regression results and data series in the appendices. Bapna's results can be verified and expanded upon because of this thoughtful inclusion, too often missing in other research monographs.

Aggregate Supply Response would not be appropriate as a text in a production economics course; it is instead a careful piece of empirical research that adds to currently accepted thought about the responsiveness of farmers in developing countries. Most graduate students working in this area would find much in this book to guide them through their own empirical efforts. One can hope that Bapna's next book will go beyond the technical discussion of supply and address more fully the implications that follow from the various estimates.

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Brandt, W. ***North-South: A Program for Survival.*** **Cambridge MA: MIT Press, 1980, 304 pp., $4.95.**

Sewell, John W. ***The United States and World Development: Agenda, 1980.*** **New York: Praeger Publishers, 1980, 242 pp., price unknown.**

North-South: A Program for Survival is the report of an International Commission, chaired by former West German Chancellor Willy Brandt, comprised of representatives of ten developing countries and seven developed countries. *The United States and World Development: Agenda, 1980* is a staff report of the Overseas Development Council (ODC), an independent, policy-research, consulting and lobbying group concerned with U.S. development policy. These reports are quite similar. In many places the ODC report quotes the Brandt report, and many of its recommendations are explicitly based on that report.

Both reports take the "enlightened self-interest" approach to selling increased international support for developing countries. The Brandt report uses the increased interdependence, "one-boat" argument; the ODC report used the "increased U.S. exports" and "increased political stability" arguments. Both reports take the basic-needs view and call for greater international committment to development. Both reports are aimed not only at policy makers but also at improving public opinion.

The Brandt report focuses mainly on international measures for improving development prospects. It devotes only one chapter to discussions of domestic structural change. The ODC report is a little more evenhanded in both tone and substance, but its main focus still is on what the developed world can do for the developing world rather than on what the developing world can and must do for itself.

The policy recommendations of the Brandt report provide a large, somewhat undifferentiated shopping list. As a result, one can find support in the report for almost any policy, ranging from radical restructuring of domestic and international economic and power relationships to policies (such as international grain reserves and commodity price stabilization) which, if pursued, would surely reinforce the existing distributions of wealth and political power.

The need to redress past imbalances between industrialization and rural development is stressed in both reports. A tripling of international assistance to agriculture and a 50% increase in agricultural investment from domestic sources are recommended. Both endorse the recommendations for tenurial reforms of the 1979 World Conference on Agrarian Reform and call for supporting packages of increased credit, agricultural extension, fertilizer, and research. International commodity and price-stabilization agreements, grain reserves, and liberalization of trade in food and other agricultural products are recommended in both books.

Both reports stress greater employment creation in industry and the role of international trade and industrial exports in employment creation. Developed nations are called upon to undertake the necessary internal structural readjustment policies required to absorb increased LDC imports. The Brandt report does not call for shifting emphasis in developing countries toward labor-intensive industries and processes of production, while the ODC report does. As a result, the section on industrial policies is the weakest part of the report of the Brandt Commission.

The major "radical" recommendations of the Brandt report deal with development finance. The Commission recommends: a system of universal revenue mobilization including developing countries on a sliding scale; an increase of official development assistance from OECD countries; and automatic revenue transfers based on taxes on "international trade, arms production or exports, international travel, and the global commons, especially seabed minerals." The latter category consists of a grab bag of internationally moving goods and people and some pet peeves. In addition, the Commission calls for a reassessment of the "conditionality" of International Monetary Fund lending and for a doubling in the current ratio of lending to capital of the World Bank. The ODC endorses most of the international finance recommendations of the Brandt report but is more modest in its numerical targets for increased aid.

The Commission also recommends the establishment of a new international financial institution—a World Development Fund—to supplement the World Bank and to remedy two complaints that developing countries have about the World Bank: too little participation in decision making and management and little, if any, program (i.e., unconditional) lending. (The ODC does not follow this last recommendation.)

In summary, both reports are good reflections of the liberal/establishment—radical, reformist perspective on national and international development policies and restructuring with which I would ally myself. Were I to write such a report, I would put somewhat greater emphasis on structural change within developing countries. Unlike either report, I would also recommend conditionality of international flows upon domestic commitment to poverty eradication and avoidance of at least gross violations of human rights. But, then, I do not have to reflect the varied political interests and viewpoints of an International Commission or to influence the U.S. Congress.

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Gardner, Bruce L. *The Governing of Agriculture.* Lawrence: The Regents Press of Kansas, 1981, xii + 140 pp., $8.90 paperback.

Gardner's theme in this short, analytical book is never in doubt: "The search for solution to agriculture's problems through governmental intervention has been and will continue to be a costly delusion" (p. 130). The solution? Phase out major parts of current farm commodity programs and ease into market approaches.

Drawing upon 1978 farm income and asset data and 1975–77 IRS data, Gardner concludes that, on average, after-tax income of farm families is probably no less than that for nonfarm families. For those rural-farm families who are in poverty (14% by Census definition in 1975–77), commodity programs by their very nature offer no solution.

Chapters 2 and 3 consist of brief, analytical descriptions of the principal instruments by which commodity and regulatory policies are administered. The treatment of commodity programs is incisive and insightful—a useful contribution to those wishing to understand the essential economic parameters and functions of the programs without the clutter of laws dating from the 1930s.

The heart of the book is in chapter 4, in which Gardner examines the public interest in agricultural policy: "When a policy generates gains to some and losses to others, it is in the public interest only if the gains are greater than the losses" (p. 64). He estimates that for 1978/79 net social losses (gains to producers less losses to consumers and taxpayers) of support programs for major crops totalled $1.5–2.0 billion. The longer-run distribution of gains ($6.4 billion in 1978/79) from supply-restricting commodity programs devolves primarily to owners of land—a class of which there is even less justification for income transfers than for relatively well-off commercial agricultural producers, according to Gardner.

Gardner marshalls his facts and builds his case in a skillful, selective way employing neoclassical economic theory as his analytical framework. On the whole his estimates and judgments are plausible. But it must be recognized, as does Gardner himself, that his assumptions are at times "sweeping," and his omissions substantial. For example, costs of externalities are not explicitly incorporated into his estimates. I agree that measurement and evaluation of externalities are difficult, but I do not dismiss their importance in commodity policy issues as readily as does Gardner. Nor would I dismiss so easily as he does the distributive issues between consumers and producers.

If commodity programs have resulted in significant net social costs and are ineffectual for antipoverty purposes, and if the gains have accrued primarily to a small, relatively well-off group (commercial producers and landowners), are there other grounds which warrant government intervention in agriculture? In a limited way, answers Gardner.

His prescriptions include a gradual phasing-out of supply-restricting commodity programs in favor of greater use of futures markets and repeal of legislation prohibiting options markets for agricultural commodities. In lieu of government-managed farm income stabilization schemes through complex storage and loan programs, Gardner suggests that the use of commodity options markets "would be an excellent substitute for . . . current farm programs for grain, rice and cotton" (p. 9). But Gardner also favors an explicit government stockpiling policy to help stabilize consumer prices, ensure supplies for food aid purposes, and forestall macroeconomic dislocations from variable agricultural production. For this purpose government itself could enter the options markets to acquire grain for storage or foreign aid commitments.

Recognizing "that the market as an institution has often malfunctioned in the face of the uncertainty and complexity of agriculture" (p. 118), Gardner prescribes certain other government actions including effective antitrust policies rather than producer monopolies to deal with problems related to concentration of economic power; public market information systems and research; less market regulation related to transportation, public health, labeling, etc.; macroeconomic policies to control inflation; negotiations with foreign governments to facilitate trade.

Gardner's analyses and recommendations deserve serious attention. Public support for current complex and costly commodity programs is waning. Their defense in the legislative and budget committees of the Congress has become increasingly difficult and less credible. I am much less sanguine than Gardner concerning the merits of commodity futures and options markets for income stabilization purposes. One of my principal reservations concerns accessibility of reliable, timely information required for effective and equitable use of those devices. Even larger commercial farmers could find themselves disadvantaged in access to such information.

Gardner has treated his subject in a careful, analytical, scholarly manner. He does not hesitate to draw judgments from admittedly thin data and simplifying assumptions. His "free market" values from the Chicago school are clearly evident and shared unabashedly. We need more such critical, well-reasoned policy studies.

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Resources for the Future

Khan, Mahmood Hasan. ***Underdeveloped and Agrarian Structure in Pakistan.*** **Boulder CO: Westview Press, 1981, xviii + 308 pp., $22.50.**

In his widely acclaimed book on Islam in four countries, V. S. Naipaul asks rhetorically of Pakistan, "Wouldn't it have been better for Moslems to trust less to the saving faith and to sit down hardheadedly to work out institutions?" The Khan book under review here shows how flawed some of these resulting institutions are in fact.

Indeed, while the transition from feudalism to capitalism is occurring rapidly, most recently propelled by the green revolution, the result is a more polarized society. The land reforms of 1959 and 1972 accomplished little; or perhaps better said, their modest effects were quickly swamped by the much greater force of new technology, increased exposure to markets, greed of the upper classes and powerlessness of the lower, participation in irrigation schemes given by the government to civil and military bureaucracies, and so on. Rich peasants and landowners are major beneficiaries of rising agricultural prices and public spending.

More specifically, Khan demonstrates that there are three salient features of Pakistan's bipolar agrarian structure in the Indus basin which make possible this uneven distribution: (*a*) To a greater extent in Sind than in the Punjab, there is a high concentration of landownership, and landowners are often absentee. Their land is often leased out in small plots to landless sharecroppers. (*b*) Feudal tenancy has declined in much of the irrigated Punjab and has given way to commercialized agriculture based on hired labor and machines. There is, argues Khan, a substantial recent resumption of land by landlords. In some areas small plot holders are leasing out their land to rich peasants and landowners. In this manner, some owners become hired workers on their own land. Statistics show a marginal reduction in landownership concentration lately, but that operation is becoming more concentrated. (*c*) Notwithstanding the former, there are growing numbers of small plot owner-operators, and this results from the development of more commercial relationships within agriculture, high population growth, and land reforms.

Based on goals of equity and efficiency, Khan recommends a land reform which would place lower ceiling limits than the present ones—50 and 100 acres in the case of individuals and families, respectively, in irrigated regions, and 75 and 150 acres in rain fed regions. Limits would apply to ownership and operational holdings and make possible the acquisition of 5 million acres in the Punjab and Sind (more than twice the area resumed by the government in both land reforms). Beneficiaries would be landless sharecroppers and marginal plot peasants and would total between about 511,000 and 644,000 new owners.

Concurrently, because of the tendency to fragmentation, a floor will have to be set; tenancy will have to be regulated (all who need land will not be able to get it because of population pressure); services will have to be provided to the new landholders; administration of the reform will have to be streamlined and decentralized; an allowance for promoting peasant organization will have to be made; current land fragmentation will have to be corrected; and a progressive land and income tax will have to be designed. In this plan production should not suffer because evidence shows that small ownership and operatorship units have higher per acre productivity.

These last chapters of the book on land and tax reforms take on a rather unreal, almost utopian character, given Pakistan's history and the recent experiences of other Asian and Latin American countries. Each time "consolidation of fragmentary plots" is mentioned, for example, the question, "Where do displaced peasants go?" should be addressed. Each time "popular participation" comes up, the question, "How is this possible given the current military government?" should be answered. That these problems—and many more like them—are not tackled in the book is no real surprise because there seem to be no good solutions. But those who work on agrarian structure in the coming decade will have to do more than repeat the old policy prescriptions, which have sounded pretty much the same for the last fifteen or twenty years regardless of country.

Khan, Carl Gotsch, and Keith Griffin agree that the last fifteen or so years have added to the polarity of Pakistan's agrarian structure. Meanwhile, Chaudhry's study of two years ago concludes that income distribution became less skewed between 1960 and 1972 (p. 188). Part of the difference flows from the primacy Khan assigns to the operatorship over the ownership concept, the opposite ordering to the one Chaudhry utilizes.

Pakistan is to Islam what Israel is to Judaism. And, like Israel, Pakistan was also created out of the dissolution of the British empire and is the product of mass migration. The problem is that, by comparison, Israel's institutions seem flexible, adaptable, and resilient, while, according to Naipaul, "out of its Islamic striving, Pakistan has undone the rule of law it inherited from the British and replaced it with nothing." Exaggeration? Probably. But Khan's study of agrarian institutions takes on more meaning when read against the textured backdrop designed by Naipaul.

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Naipaul, V. S. *Among the Believers: An Islamic Journey.* New York: Alfred A. Knopf, 1981.

Leistritz, F. Larry, and Steven H. Murdock. ***The Socioeconomic Impact of Resource Development: Methods for Assessment.*** **Boulder CO: Westview Press, 1981, xviii + 286 pp., $23.75.**

The authors define impact as "the phenomenon of rapid change in established economic, demographic, and social structures, usually geographically localized, caused by large-scale, precipitous growth or decline in an area's economic base" (p. xiii). The types of impacts for which the authors develop assessments (resulting in a separate chapter for each assessment) are those of the social, economic, demographic, public service, and fiscal changes resulting from resource developments. A consistent framework is used in developing the assessments and constitutes the subheadings for each of the five assessment chapters. This framework examines the following topics: (*a*) the conceptual basis of the alternative methods used in the given area of impact assessment; (*b*) the key impact and policy decisions of the given impact; and (*c*) the actual projection techniques employed in current impact assessments. In addition to the five assessment chapters, separate chapters cover the areas of interfacing socioeconomic dimensions, computerized impact projection models, use of assessments in the policy process, and the usual introduction and summary.

The authors have done an exceptional job of reviewing the literature in this relatively new socioeconomic area of impact assessment and include a twenty-five-page bibliography. As one of the first attempts to organize the material of socioeconomic impact assessments, the authors have used a rather rigid framework which enhances its readability but limits creativity in comparing this area with other areas of social science research, such as benefit-cost analysis or regional growth and development. One is left with the impression that the authors have geared the book to those interested in a single source reference for preparing environmental impact statements under the National Environmental Policy Act. The intended audience, of course, is much broader than this; and many professionals at local, state, and national agency levels would benefit from the state-of-the-art reviews. The book is unique within our own profession for combining materials from sociology, demography, regional growth, as well as economics, to form a complete and total assessment of a resource development project.

The impact assessment chapters, in general, are excellent. Discussing the impacts as separate components leads to much repetition among the chapters, but this is probably useful when using the book as a reference for a particular impact assessment. The economic, demographic, and fiscal impact chapters are complete and thorough analyses. The public service impact chapter slips into the jargon and approach of public service "requirements" with the consequent price inelastic assumption. This leads the authors to state that "it is evident that many services in rural areas are inadequate" (p. iii). The chapter on social impact assessment starts out by recognizing that this is an often-neglected and ill-defined area of impact assessment. This fact is not disputed. However, it is the opinion of this reviewer that the authors have not helped the cause. The chapter contains many qualifying statements about why this is a difficult area and includes much of the usual sociology jargon on organization, conflict, and perception. This is one area where examples of completed impact assessments would help the reader in visualizing the desired outcome.

The chapter on interfacing is the lead-in for the chapter on computerized impact projection models. The latter chapter is an excellent description and analysis of some thirteen computerized socioeconomic impact models. A historical development of computerized assessment models is given with all of the attendant references. The authors are to be commended for their concern to provide numbers to local, state, and national officials on which to base planning decisions or policy. However, one must think that the only results of assessment studies are those that come out of a computer model. No alternatives are discussed.

The chapter on use of assessments in the policy process fails to point out some of the dangers in applying impact assessments. It must be remembered that impact analysis does not answer the question of why the impact. Only the expected results of the exogenously determined change on the region, state, or city are the purview of impact assessments. Impact analysis does not deal with the question of whether or not project investment is economically or socially desirable. And yet, the public and local officials in many instances would like to use the results of impact assessments to justify or oppose project investment. The completely different analytical approach of social benefit-cost analysis is needed to evaluate the economics of project investment. Confusion between the two approaches has led local officials to justify purchasing locally produced goods and services at higher prices because the apparent impact is more local jobs despite overall project costs well in excess of benefits.

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Note from the Book Review Editor

The three reviews which follow all pertain to volume 3 of a *Survey of Agricultural Economics Literature*. Basically the same procedures were used for reviewing this volume as were used in reviewing the first two volumes (see the May and November 1978 issues of this *Journal*). Again, three individuals were asked to review independently volume 3, with the order of the reviews determined alphabetically. It was requested that the first review be a little longer than the others to include a summarization of the contents of the entire volume in one place, permitting the other two reviews to concentrate more on evaluative aspects. Thus it is intended that the reviews be viewed as a combined set rather than individual pieces.

Martin, Lee R., ed. ***A Survey of Agricultural Economics Literature, Volume 3.*** **Minneapolis: University of Minnesota Press, 1981, xiv + 653 pp., $35.00.**

The *Economics of Welfare, Rural Development and Natural Resources in Agriculture* is the third volume of a comprehensive survey of agricultural economics literature covering the post-World War II period. The articles in this volume, with one exception, make limited reference to pre-1940 literature. All have good coverage of literature published through 1975 and most through 1978. A postscript on one article covers the 1977–80 period.

The subject areas covered in volume 3 are diverse: part 1, "The Economics of Rural Poverty"; part 2, "Rural People, Communities, and Regions"; part 3, "Natural Resource Economics"; part 4, "Organization and Performance of Agricultural Markets." Whereas volume 1 dealt with traditional fields and volume 2 with quantitative methods, this volume does not have a unifying theme. Parts 1 and 2 would be expected to appear in the same volume; part 3 tends to have its own domain. Perhaps most surprising to the reader will be the inclusion of part 4. The subject matter of this part is not reflected in the title of the volume and could easily have been included in volume 1.

This is a large volume, 653 pages. In sheer size, it exceeds volume 1 by 113 pages and volume 2 by 180 pages. It has the same desirable physical characteristics of the first two volumes.

Part 1 consists of a single article coauthored by Bryant, Bawden, and Saupe. It begins with a useful introductory section which delineates boundaries for the article and signals its structure. The authors focus on the poverty of people rather than place, and they emphasize literature concerning the distribution of income and wealth because they believe this to be a large part of the rural poverty problem.

The authors greatly enhance the potential usefulness of their work by providing mini-introductions and summarizing paragraphs for each of the major sections. They generously share their professional assessments in terms of conclusions that can be drawn from the literature on a given topic, defects that exist, and priorities for further work.

Bryant, Bawden, and Saupe win the prize in this volume for the longest list of references, 75 pages or approximately 1,400 citations.

Part 2 deals with rural development and consists of three chapters plus an introductory section by Tolley. In the first chapter, Edwards examines the "Bases for Regional Growth." This is a comprehensive, detailed survey of the literature on economic growth encompassing major contributions going back to Adam Smith. The organizing construct is a set of five principles, or theories, identified as bases for regional growth: increasing resource availabilities, advancing technology, expanding markets, conquering geographic space, and building institutions. The author states that no effort is made to synthesize the findings or to assess relative importance. Tolley points out that an implication of Edwards' work is the need for a fuller integration of the five elements (bases).

Clearly there are limits to what can be asked of an author. Nevertheless, I believe that readers would have benefitted from the insight that Edwards must have gained on relative importance of different approaches, ideas on most fruitful avenues to pursue, and generally his professional appraisal of the literature on economic growth. The reader of this chapter is advised to read the conclusions section (pp. 247–52) and Tolley's introduction before proceeding to the body of the work.

The second chapter is titled "Rural Development: A Review of Conceptual and Empirical Studies," by Jansma, Gamble, and Madden, agricultural economists, and Warland, a rural sociologist. The authors deal quickly with defining rural development and the complex problem of what to include, deciding to focus on social and economic aspects, the role of organizational and institutional forces, and the impact of alternative spacial arrangements. They make good use of examples and do an excellent job of synthesizing what is known and interpreting the current state of rural development literature.

Graves and Clawson coauthored the third chapter on "Rural to Urban Migration: Population Distribution Patterns." An interesting feature of this short essay is the presentation of a proposed new conceptual foundation for organizing the literature on issues related to human migration decisions.

Part 3, "Natural Resource Economics, 1946–75," is coauthored by Castle, Kelso, Stevens, and Stoevener. This article merits special recognition and may well become a classic reference. It offers a rare opportunity to view an identifiable field of applied economics from the perspective of four individuals who are major contributors to the field and whose professional careers span the period under consideration.

In the first section, the authors present an intellectual genealogy of natural resource economics which covers the emergence of land economics and the evolution to natural resource economics. Next, they review the theoretical and analytical bases of the field. Included is a thought-provoking survey on how a changing social environment impacts on the thinking and activities of agricultural economists. Also included is a vignette on the influence of production economists, namely, Heady and Johnson, on the development of resource economics. The authors proceed to review systematically the several areas of application of natural resource economics and conclude with a valuable section on the continuing evolution of the field.

This article deserves to be included as assigned reading in any resource economics course from upper level undergraduate through Ph.D. seminars.

Part 4 is coauthored by Helmberger, Campbell, and Dobson and deals with "Organization and Performance of Agricultural Markets." The literature in agricultural marketing is surveyed from the industrial organizational point of view. The familiar concepts of structure, conduct, and performance are present. However, the application of the industrial organizational framework of analysis to agricultural markets and the use of this framework to organize the diverse literature pertaining to agricultural markets is well done. If not a new approach, it is certainly a refreshing treatment.

Strong features of this article include the emphasis placed on causal relationships and a conscious effort to interpret and evaluate the literature reviewed. After presenting the framework for industrial organization, the authors deal with competition in agricultural markets, the cooperative enterprise, marketing information, grades and standards, market performance in space and time, and vertical organization.

The authors conclude that more attention to vertical coordination systems is a high priority for better understanding our food and fiber system. Finally, on the matter of research progress, the authors offer an insightful gem: "The lifelong study of futures markets by H. Working [1949], a small note on stabilization by Waugh [1944 or 1971], an excellent industry case study by Nicholls [1941], a simple comparison of industry profits with concentration ratios by Bain [1968]—these are the stuff of which progress is made" (p. 625).

Editor Lee Martin and the authors of volume 3 are to be commended for an important contribution to present and future agricultural economists. Teachers, researchers, and extension educators will benefit from having this volume as a ready reference.

David H. Boyne
Ohio State University

A Study of Agricultural Economics Literature, Volume 3.

Like the preceding volumes of the postwar literature review, volume 3 will be of tremendous assistance to retrospective searches of the literature by providing an organized guide to a large list of substantive references. The authors, in preparing their survey of the literature, faced three major tasks: (*a*) organizing the literature and their survey in some meaningful way, (*b*) summarizing and critiquing the principal findings, and (*c*) pointing to gaps in the knowledge base to which future research might be directed. The first task of organizing the survey effort is the most difficult, particularly in subject areas for which there is not a well-developed theoretical framework but rather a series of clusters of hypotheses. This is precisely the problem facing the authors of parts 1 and 2. The authors of the various chapters handle this problem quite differently and with varying degrees of success.

Despite the existence of a fragmented theoretical base to aid the organization of the literature, the authors of parts 1 and 2 have done an exceedingly competent job of pulling together the research findings of the postwar period and of pointing out the deficiencies of that work. With the limited space available to a reviewer, it would be unwise to attempt to summarize the authors' summaries of a multitude of research efforts. Instead, this review will try to give you a flavor of some of the authors' suggestions for future directions of research.

The authors of the poverty chapter have sprinkled their suggestions liberally throughout their effort. Key among their suggestions are (*a*) the need to develop a coherent theory that explains the determinants of the distribution of income between generations, (*b*) the need to develop longitudinal data so that life cycle income streams can be discovered and used as the basis for estimating full or permanent and transitory income in order that the permanent poor can be distinguished from the transitory poor and appropriate policies designed for each, and (*c*) the need to merge the ideas contained in the Tweeten-Brinkman attempt at a stagnation theory with the ideas flowing from the Schultzian industrial-urban hypothesis to create a theory of area poverty.

The "Bases for Growth" chapter identifies five bases of growth (sets of variables): (*a*) increasing resource availabilities, (*b*) advancing technology, (*c*) expanding markets, (*d*) conquering space, and (*e*) building institutions. The author notes that most research efforts tend to concentrate on one or two bases of growth. He suggests a systems approach, indicating that as the "five analytic bases for growth continue to be incorporated in theoretical and empirical studies in a fashion which treats all with equal potential for explaining growth, it will be found that all five interact simultaneously in the growth process and that no single one will prove to be the exclusive basis for growth." And he adds that growth policies will need to be responsive as one basis for growth or another presents itself as the bottleneck. Finally, the reviewer cannot resist the temptation to suggest a careful reading of the section of this chapter dealing with building institutions. It will be helpful, particularly to those most comfortable with neoclassical microeconomics ideas.

The chapter on rural development has the most difficult problem of organizing the literature. It appears relatively unstructured, when in fact it suffers from excessive structuring. The chapter attempts to focus on (*a*) social and economic aspects of economic development, (*b*) the role of organizational and institutional forces, and (*c*) the impact of alternative spatial arrangements. The authors superimpose on that structure a division of the literature into two parts that deal with the conceptual base and with the application of concepts. This excessive structuring, combined with a fragmented conceptual base, puts an excessive burden on the reader in his attempt to relate the conceptual base to the empirical work. Overall, this chapter is an excellent survey and is strong in its critique of the postwar literature. But the suggestions for future directions of research are either sparse or subtle, or both.

As one might suspect, there are areas of overlap between the Edwards and the Jansma et al. chapters. The thrust of the latter chapter, however, is toward the distribution or equity aspects of growth and toward a more micro, or community, level of observation. The emphasis on community reinforces the need for criteria for community or regional delineation. Spatial delineation based on functional logic seems appropriate, but the criterion of large enough to be economic and small enough to show specific development problems is of little assistance. Perhaps future research should emphasize the criterion of small enough not to mask over development problems combined with a model structured to reflect the linkages of smaller communities to larger communities with respect to inputs and with respect to goods and services.

The migration chapter suggests that future directions of migration research should utilize a simultaneous system reflecting the factors shaping changes in the demand for, and supply of, labor. This formulation is based on the concept of two migration triads, one reflecting a perfect spatial information and mobility world with instantaneous adjustments and an amenity demand emphasis, the other an imperfect spatial information and mobility world with lagged adjustments and a job search emphasis.

This review has not considered parts 3 and 4, which constitute nearly 40% of volume 3. But those economists concerned with poverty and growth or development will find in volume 3 a wealth of knowledge and stimulation as they look to the future.

Lee M. Day
Cornell University

A Survey of Agricultural Economics Literature, Volume 3.

Reviewing this volume is a challenging task. The authors provide a comprehensive overview of the post-World War II literature in the areas reviewed. While they undoubtedly overlooked publications whose authors believed they should have been included, the authors of this volume can only be commended for the generally expert way in which they sifted a great deal of wheat from the chaff that has been published in the last forty years.

This review will proceed by considering each section of the book in turn. The reviewer makes no claim for even treatment of all sections because of his own limitations and because of the varying lengths of the several sections. Some overall observations will conclude the review.

In part 1, some of the urban bias in poverty programs is attributed to the failure of the agricultural economics profession in providing timely and comprehensive research to inform policy makers of the nature of rural poverty. This indictment is later extended to the other social sciences. While I expect that agricultural economists do deserve some of the blame, that blame must also be shared by those who fund social science research and who have preferred that agricultural economists work with the traditional clientele groups.

An erroneous statement appears on page 18, where the authors cite a proposed definition of poverty as "those whose income is below one-half of the income of the median family" and indicate that this definition will always result in a constant fraction of the population being in poverty. This statement is correct only if the shape of the income distribution remains constant, at least for that portion of the distribution below the median income.

Part 2 consists of a series of essays. The first essay relates the many descriptive studies of the bases for regional growth to some of the more theoretical literature from general economics. One is impressed by the descriptive nature of the agricultural economics literature and by the differences in emphasis among authors.

The second essay questions the widely used Pareto optimality model but notes that it is commonly used in the literature. In this essay, as in the previous one, the lack of attention to the Marxist paradigm may be noted. From a world perspective, the Marxist paradigm is used by many agricultural economists as they study problems of rural development and regional growth. There is also surprisingly little attention given to the distribution of power, either economic or political, and its impact on rural development.

The third essay concerns rural-to-urban migration and population distribution patterns. It reads more like a personal essay than a literature review. The authors provide extensive references but fail to integrate them into the essay. The close relationship of migration patterns and settlement patterns is emphasized. Two migration triads are presented and synthesis is attempted. Unfortunately, there is inadequate discussion on how one would relate the synthesis to potential empirical models and real-world data.

In part 3 an interesting, intellectual genealogy of natural resource economics is provided which offers a perspective often lacking in literature reviews. The profession is challenged to change institutions from exogenous to endogenous components of the model. This challenge is well developed and should provoke further research in an especially productive area for the future development of agricultural economics.

There is some unevenness in part 4 which suggests that individual authors may have been responsible for a specified portion of the total review. The final integration reflects some differences in style and perspective.

On page 507 the authors indicate that evaluation of progress in the published literature involves determining whether or not the literature contributed to our knowledge of and ability to understand the phenomena that comprise agricultural marketing and the extent to which the literature serves as a basis for government policy aimed at increasing social welfare. Apparently literature which contributes to private decision making is of no value, even if improved private decision making leads to an increase in social welfare. Within the paragraph there is an apparent contradiction where the authors later indicate that "advances in knowledge are sought mainly because they support higher levels of living." However, on page 553 the authors again indicate that "it is not sufficient to evaluate observed performance without at the same time assessing what performance would be under alternative government policies."

Marketing orders and agreements are not treated in a separate section but are discussed briefly in the section on cooperative enterprises. I would have preferred increased emphasis on that topic as well as on futures markets. In view of the large growth of futures markets in recent years for both agricultural and nonagricultural commodities, scholars need to understand how futures markets have performed for traditional agricultural commodities.

There is some duplication in parts 1, 2, and 3 of this literature review. For example, income distribution is discussed, albeit from a different perspective, in each part. A topic index might have been a useful addition for the reader interested in pursuing topics across the divisions used in organizing the book.

Several chapters suffer because they probably were completed several years prior to publication since the most recent literature cited often was dated 1977. Perhaps the editor should have indicated the dates the manuscripts were received in final form. Jansma et al. added a postscript to reflect some of the more significant literature published after their review had been completed.

In summary, this is an excellent book. The deficiencies are minor relative to the wealth of literature citations and the cogent summarization of significant findings in each of the several fields. The authors and the editor are to be congratulated for a job well done.

Lester V. Manderscheid
Michigan State University

National Research Council. *Surface Mining: Soil, Coal, and Society*. Washington DC: National Academy Press, 1981, xiii + 233 pp., $11.50.

This new study is a good follow-up to a predecessor National Resource Council study entitled *Rehabilitation Potential of Western Coal Lands* (1974), benefitting from six additional years of research and experience in reclaiming surface-mined lands and pioneering national legislation (Surface Mining Control and Reclamation Act of 1977). The book addresses the effects of coal surface mining on soil from two major perspectives—institutional (chaps. 1–4) and scientific (chaps. 5–7). Each perspective is well-treated, though the linkage and transition between the two perspectives appear somewhat disjointed.

The study develops the institutional perspective on reclamation using some concepts from environmental economics and social choice theory, for example, the need to internalize the external costs associated with surface mining and intergenerational equity concerns. To the extent that these costs are not reflected in market prices, collective decisions, such as the Surface Mining Control and Reclamation Act, are made to correct the external costs and resulting inefficiency in resource use. The study appears to have missed an opportunity to contribute in analyzing the effectiveness of the legislation in efficiently allocating resources, in equitably sharing the costs of reclamation, and in its implications for private property rights. With respect to the latter point, one might argue that the Surface Mining Control Act does not reassign property rights from the private to the public sector but rather narrows private property rights to land by restricting the exercise of those rights. The study offers alternative approaches to controlling surface mining effects, such as replacing design standards with performance standards, developing a new system of economic incentives, and developing new forms of property and institutions. A minor point applicable here is that the study is a little repetitious in some parts. One example of this is the discussion of alternative approaches to reclamation.

From a scientific perspective, the Council recommends the adoption of an "appropriate" approach to reclaiming the nation's coal-bearing lands, assuming that an appropriate goal for reclamation is to ensure that society does not lose important land use opportunities that were available prior to soil disturbance. The "appropriate" approach to reclamation is not simply the proper replacement of soil horizons but rather regaining or bettering the productivity of premined soils. In other words, reclamation should aim at establishing physical, chemical, and biological processes conducive to productivity rather than merely replacing the soil in the order in which it was found. The questioning of society's goal in reclamation and stressing results rather than the method of soil replacement is incisive and a contribution to analysis.

Chapters 5–8 deal with the soil characteristics in the coal-bearing regions (Appalachia, Midwest, and West), the reclamation strategies, and the costs of reclamation and are particularly useful and informative. Several reasonable and innovative suggestions are offered for consideration. For example, land should be reclaimed to the contour most advantageous for its final use regardless of whether the contour approximates the original one. Also overdeveloped soils, such as those in Appalachia, may be rejuvenated by mining, and productivity possibly equaled or exceeded where high quality substratum is available. Periods of five to ten years may be too short to achieve species diversity. Rather, the appropriate criterion for successful reclamation may be ecosystems in intermediate successful stages, tailored to the individual mining site.

Continuing with the scientific perspective, the study also addresses soils and hydrologic balances from the standpoint of infiltration capacity. It would have added to the comprehensiveness of this study if hydrologic balances would have included a summary of the research on reestablishing groundwater flows in replaced overburden after water-bearing coal seams are removed.

In examining reclamation costs for the three major coal-bearing regions, the study concludes that current estimates are on the high side, though they should be reduced with experience and economies of scale. It further concludes that mining in areas where reclamation is relatively easy and inexpensive should be encouraged and that standards required to protect fragile lands in one region should not be required in all regions simply to maintain equity among regions.

The treatment of reclamation from the two perspectives is extensive and well done. Because the study also summarizes much recent research on reclamation results and costs, it is an excellent up-to-date reference for one's personal library. For those readers not totally captivated by the technical aspects of surface mining on soil, chapters 3 and 4 offer a convenient summary of surface mining as a collective-choice issue and alternative policy instruments in dealing with the external costs associated with mining. *Surface Mining* is a solid base upon which to rethink our national policy on surface mine reclamation.

Constance Boris
University of Michigan

Schmandt, Jurgen, et al. *Nutrition Policy in Transition*. Lexington MA: Lexington Books, 1980, xxv + 289 pp., $29.95.

This book deals with the nutrition problems in society that affect health and productivity and governmental policies designed to alleviate those problems. It provides a comprehensive review of nutrition issues, describes current policy approaches to deal with these concerns, and proposes a set of goals to assist in the development of a new nutrition policy. The book evolved from a series of student research papers produced as part of the Nutrition Policy Research Project at the Lyndon Johnson School of Public Affairs at the University of Texas.

The "transition" in the book's title refers to a change in the types of nutrition issues that might be addressed by public policy makers. Existing programs and policies deal primarily with problems of underconsumption or of otherwise inadequate diets usually associated with poverty. The poverty-related nutrition problems that gave rise to current food assistance and nutrition programs still exist. However, interest in nutrition policy now extends beyond nutrient deficiencies and poverty-related problems. These new interests stem primarily from research on relationships between food consumption behavior, particularly overconsumption, and human health and productivity. For example, associations between diet and the incidence of major diseases, including cardiovascular diseases, arthritis, and some forms of cancer have been established.

The stated topic of this book is the development of new goals and strategies for this more comprehensive nutrition policy. Most of its pages, however, are devoted to descriptions of existing programs and policies. This background information, all presented in a well-documented and readable fashion, is the strength of the book.

The book is a useful reference for students of nutrition policy or persons wishing to become familiar with nutrition-related programs. Chapters cover what is known about the nutritional status of the population, the policy environment in which nutrition interests must operate, and federal and state nutrition programs. Also included are chapters summarizing current knowledge on the relationship between diet and health and on the state role in developing nutrition policies and programs. The state of Texas is used as a focal point in much of the discussion. The examination of the state role is particularly interesting in light of current reductions in federal food assistance programs and the transfer from the federal to state governments of some program responsibilities and resources.

While supplying useful information and analysis of the current state of affairs, the authors are less successful in providing a rationale for, or guidance in, the "transition" to a new nutrition policy. It may be evident to most people that diet affects health far beyond the avoidance of nutrient deficiency diseases. For example, many believe that changes in the current American diet, such as substantial reductions in consumption of sugar and fat, would improve the general state of health. Nonetheless, it is not clear that we know enough about these more subtle aspects of the diet-health relationship to begin to fashion public policies or programs to alter food consumption behavior. Nor is it clear that any attempt to change diet patterns beyond providing information for informed choices is appropriate.

General discussions of a new nutrition policy, such as are put forth in this book, are not premature, though the large gaps in our knowledge about food consumption behavior and the diet-health link make development of a more comprehensive policy difficult. A guide to practical policy development is, perhaps, too much to expect, given the often tentative nature of research results on the implications of diet choice on health and productivity. A clearer picture of effective and appropriate public policies should develop as behavioral and epidemiological research results on the diet-health link become less tentative. This book provides a good beginning, though, by supplying essential background material and by raising appropriate issues.

Roger Hitchner
Congressional Budget Office

Ph.D. Recipients by Subject, 1981

Agricultural Economics, General

John Crisler Wilson, B.S. 1964, M.S. 1966, Ph.D., Mississippi State University, "Estimated Cost Structure for New and Existing Specialized on-the-Rail Beef Slaughter Plants in Mississippi."

Agricultural Finance, Capital, and Credit

Mark R. Drabenstott, B.A. 1977, Earlham College; M.S. 1980, Ph.D., Iowa State University, "Capital and Credit Demands in U.S. Agriculture: Projections for Alternative Economic and Policy Environments."

Gayle Woodcock Morris, B.S. 1972, M.S. 1975, Bowling Green State University; Ph.D., University of Nebraska, "An Economic Evaluation of the Beneficio System of Coffee Credit Delivery, and the Allocation of National Funds to the Coffee Subsector of Costa Rica."

Edouard K. Tapsoba, B.S. 1971, Laval University; M.A. 1977, Ph.D., Michigan State University, "An Economic and Institutional Analysis of Formal and Informal Credit in Eastern Upper Volta: Empirical Evidence and Policy Implications."

Severino Bawiin Vergara, B.S. 1971, M.S. 1977, University of the Philippines; Ph.D., Ohio State University, "An Analysis of the Regulatory Response of Rural Banks in the Philippines: A Linear Programming Approach."

Agricultural Income; Rural Poverty

Adrian Mukhebi, B.S. 1974, M.S. 1976, Kansas State University; Ph.D., Washington State University, "Income and Employment Generation in Kenyan Small-Scale Agriculture."

Agricultural Labor; Rural Manpower

Ahmad Rostamizadeh, B.A. 1971, Tehran University, Iran; M.A. 1977, University of Southern California; Ph.D., Washington State University, "Duality between Cost and Production Functions with Application to the Agricultural Labor Markets in the United States, Washington State, and California."

Gustavo Sain, B.S. 1971, Catholic University of Mar del Plata, Argentina; Ph.D., University of California, Davis, "A Migration Model of Undocumented Mexican Workers."

Terence Sherrod, B.A. 1973, Eastern Washington State College; Ph.D., Washington State University, "The Impacts of Farm Size on the Economic Development of a Regional Economy."

John R. Shields, B.A. 1967, San Francisco State College; M.A. 1971, M.S. 1975, Ph.D., Michigan State University, "Labor Time Allocation Decisions of Low Farm Income Families in Michigan."

Agricultural Products: Demand, Supply, Prices

Karrar A. Abbadi, B.S. 1967, University of Khartoum; M.S. 1972, Ph.D., University of Wisconsin, "Analysis of World Market Demand, Supply and Price of Sudan's ELS Cotton."

Vincent Akinyosoye, B.S. 1970, M.S. 1976, University of Ibadan; M.A. 1980, Ph.D., University of Wisconsin, "Theory of Competitive Pricing and Storage under Uncertainty with Application to Soybeans."

Samm Bbuyemosoke, B.A. 1974, M.S. 1975, Makerere University, Uganda; M.A. 1977, Ph.D., Washington State University, "The Supply of and Demand for Asparagus in the United States."

Richard Robert Henry, Graduate, 1973, National Institute of Agronomy, Paris, France; M.S. 1974, Ph.D., University of California, Davis, "Short-Run Price Formation in the International Soybean Complex: A Dynamic Econometric Analysis."

Thao Khamoui, B.A. 1975, M.S. 1979, Ph.D., University of Hawaii, "An Economic Feasibility Analysis of Woodchip Production on the Island of Hawaii for Export to Japan."

David R. Lee, B.A. 1972, Amherst College; M.A. 1980, Ph.D., University of Wisconsin, "Acreage Allocation under Changing Government Feedgrain Programs."

William Luppold, B.S. 1974, M.S. 1976, University of Florida; Ph.D., Virginia Polytechnic Institute and State University, "Demand, Supply, and Price of Hardwood Lumber."

Luis Gonzaga Mendes, B.S. 1971, Federal University of Bahia; M.S. 1974, Federal University of Vicosa; Ph.D., Ohio State University, "Economic Feasibility of Alcohol Production in Bahia State, Brazil."

Gilead Isaac Mlay, B.S. 1975, University of Dar-Es-Salaam; M.S. 1978, Ph.D., Oklahoma State University, "Economic Analysis of Acreage Supply Response under Risk: The Case of Selected Crops in Oklahoma."

Stephen Lloyd Ott, B.S. 1975, Michigan State University; M.S. 1977, Ph.D., Ohio State University, "The Economics of Producing Fuel-Grade Alcohol from Corn in Western Ohio."

Daniel Otto, B.S. 1976, M.S. 1978, University of Minnesota; Ph.D., Virginia Polytechnic Institute and State University, "An Economic Assessment

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The names of Ph.D. recipients are provided by departments of agricultural economics and by departments of economics with majors in agricultural economics. The list is for degrees granted in the calendar year 1981.

of Research and Extension Investment in Corn, Wheat, Soybeans, and Sorghum."

Paulo B. Paez, B.S. 1965, M.S. 1968, Federal University of Vicosa; Ph.D., Oregon State University, "Analysis of the International Demand for Brazil Nuts."

E. Wesley F. Peterson, A.B. 1967, University of California; M.P.A. 1971, Princeton University; M.A. 1980, Ph.D., Michigan State University, "Adjustment of the Spanish Feedgrain and Livestock Sectors Following Accession to the European Community."

Mohamed Ben Senia, B.S. 1969, National Institute of Agronomy, Tunis; M.S. 1972, University of Minnesota; Ph.D., Iowa State University, "Supply Response of Cereals in Tunisia."

Thomas C. Slane, B.S. 1970, Rutgers University; M.S. 1974, University of Massachusetts; Ph.D., Pennsylvania State University, "An Econometric Model for Predicting Monthly Price and Production in the U.S. Egg Subsector."

V. Roy Southworth, B.A. 1971, University of Washington; M.A. 1976, Ph.D., Stanford University, "Food Crop Marketing in Atebu District, Ghana."

James Standaert, A.B. 1973, Gonzaga University; M.A. 1979, Ph.D., Washington State University, "A Comparison of Alternative Forecasting Methods: Econometric versus ARIMA."

Rod F. Ziemer, B.B.A. 1974, Augusta College; M.S. 1977, Ph.D., University of Georgia, "Disequilibrium in Agricultural Markets: The U.S. Beef Sector."

Economic Development, Growth and Planning

Salahuddin Ahmad, B.A. 1971, Panjab University, Pakistan; M.A. 1972, University of Karachi, Pakistan; M.S. 1975, Stirling University, U.K.; M.A. 1977, Ph.D., Yale University, "Output and Factor Market Effects of Technological Progress, Population Growth and Public Investment in Bangladesh Agriculture."

Carlos A. Barbosa Da Silva, B.S. 1976, University of Rio de Janeiro; M.S. 1979, Ph.D., Michigan State University, "Factors Affecting Enterprise Choice: An Analysis of Traditional Food Production in Southeastern Minas Gerais, Brazil."

Jagdish Bhati, B.S. 1968, U.P. Agricultural University; M.S. 1972, University of Agriculture and Technology; M. Phil. 1975, Himachal Pradesh University; Ph.D., University of Hawaii, "Population, Resource Use and Ecological Stresses in the Western Himalayas: An Integrated Strategy for Hill Area Development."

Roberto M. Bocchetto, B.S. 1966, University Catolica de Mar del Plata; M.A. 1973, Ph.D., Michigan State University, "Incorporation of Technology in the Argentine Livestock Sector from an Institutional Perspective."

Mohammad Akram Chowdry, M.Ed. 1965, University of the Panjab, Pakistan; M.B.A. 1972, San Jose State University; Ph.D., University of California, Berkeley, "Optimal Allocation of Natural Resources, Foreign Trade, and Food Requirements (A Linear Programming Model for Pakistan)."

Luis Arturo Crouch, A.B. 1974, University of California, Santa Barbara; M.S. 1977, Ph.D., University of California, Berkeley, "The Development of Capitalism in Dominican Agriculture."

Sanjay Dhar, Ph.D., Yale University, "An Analysis of Internal Migration in India."

Jaime Marcos Fernandez, LIC. en Econ. 1968, University Nacional Auto de Nicaragua; M.S. 1971, Ph.D., Cornell University, "An Inquiry into Farm Viability and the Self-Sustaining Capability of Small Farm Projects."

Christopher David Gerrard, B.S. 1972, University of Saskatchewan; B. Phil. 1974, Oxford University, England; Ph.D., University of Minnesota, "Economic Development, Government-Controlled Markets, and External Trade in Food Grains: The Case of Four Countries in East Africa."

Peter Udo Iniodu, B.A. 1970, Cuttington College; M.S. 1977, Virginia State College; Ph.D., University of Tennessee, "Small Farm Production Credit for Food Crop Expansion in the Cross River States of Nigeria."

Farrukh Iqbal, B.A. 1975, Harvard University; M.A. 1976, M. Phil. 1978, Ph.D., Yale University, "The Demand and Supply of Funds among Agricultural Households: A Theoretical and Empirical Analysis."

Carlos A. Leite, B.S. 1973, M.S. 1975, Federal University of Vicosa; Ph.D., Michigan State University, "Economic Efficiency of Grain Production Systems for Traditional Agriculture in Southeastern Minas Gerais, Brazil."

Anibal Monares, Ing. 1962, University of Chile; M.S. 1967, North Carolina State University; Ph.D., Cornell University, "The Potato Seed System in the Andean Region: The Case of Peru."

Adrian Mukhebi, B.S. 1974, M.S. 1976, Kansas State University; Ph.D., Washington State University, "Income and Employment Generation in Kenyan Small-Scale Agriculture."

Basilio Nikiphoroff, Graduate 1972, National University of Asuncion, Paraguay; M.S. 1979, Ph.D., University of California, Davis, "Economic Analysis of Paraguayan Farms under Uncertainty."

Francisco J. Proenza, B.A. 1969, Ph.D., University of Florida, "Impact of the Supervised Credit System on the Use of Modern Agricultural Practices: The Case of Corn in Guatemala."

Som Prasad Pudasaini, B.S. 1971, Rajasthan College of Agriculture, University of Udaipur, India; M.S. 1976, University of the Philippines, Los Banos; Ph.D., University of Minnesota, "The Contribution of Education to Agricultural Productivity, Efficiency, and Development in Nepal."

Carlisle F. Runge, B.A. 1974, University of North Carolina; M.A. 1980, Ph.D., University of Wisconsin, "Institutions and Common Property Externalities: The Assurance Problem in Economic Development."

Gregg Scott, B.A. 1969, University of Notre Dame; B.A. 1974, University of Oxford; Ph.D., University of Wisconsin, "Potato Production and Marketing in Central Peru."

Donald A. Sillers III, Ph.D., Yale University, "Measuring Risk Preferences of Rice Farmers in Nueva Ecija, Philippines: An Experimental Approach."

Lloyd Strachan, B.S. 1957, Ontario Agricultural College; M.S. 1958, Cornell University; M.A. 1968, Ph.D., University of Wisconsin, "Capitalism and the Peasant: Northwest Parana, Brazil."

Mohamed H. Takroni, B.S. 1971, University of Idaho; M.S. 1976, New Mexico State University; Ph.D., Oklahoma State University, "Evaluating Loan Repayment in the Saudi Arabian Agricultural Sector by Means of a Farm Credit Interdependent System."

Somnuk Tubpun, B.A. 1970, M.A. 1974, Thammasat University; Ph.D., University of Minnesota, "Risk, Allocative Error and Value of Perfect Information among Thai Rice Farmers in Channasutr Land Consolidation Area."

Hilda Yumiseva, B.A. 1970, Pitzer College; Ph.D., University of Florida, "Agricultural Policy: A Linear Programming Application to Guatemala."

Fernando Zalacain, Econ. 1966, Kiev Institute of Economics; M.S. 1973, Florida International University; Ph.D., University of Illinois, "A Regional and Interregional Input-Output Analysis of the Puerto Rican Economy."

Energy

Timothy James Considine, B.A. 1975, Loyola University; M.S. 1977, Purdue University; Ph.D., Cornell University, "A Regional Economic Analysis of Energy Pricing and Taxation Policies."

Richard Douglas, B.A. 1973, Howard University; M.S. 1976, Ph.D., University of Maryland, "The Energy Intensiveness of Maryland's Agricultural Sector and Economic Implications of Increases in Energy Prices on Maryland's Agricultural Output."

Alireza Emami, B.S. 1971, University of Tehran, Iran; M.S. 1977, Ph.D., Utah State University, "Oil and Iranian Development."

Tesfa G. Ghebremedhin, B.A. 1972, Haile Selassie University; M.S. 1976, Colorado State University; Ph.D., Oklahoma State University, "A Simulation Model for Analyzing Alternative Energy Choices for Oklahoma and Projecting Economic Variables from 1972 to 2000."

Environmental Economics, Conservation

Glenn Arthur Barnaby, Jr., B.S. 1973, Fort Hays Kansas State College; M.S. 1976, New Mexico State University; Ph.D., Texas A&M University, "Economic Implications of Pollution Control on Texas Rangeland."

Sandra F. Baron, A.B. 1971, University of California, Berkeley; A.M. 1976, Ph.D., Stanford University, "Efficiency and Secondary Resource Recovery: A Mixed Model for the Allocation and Recovery of Municipal Refuse."

Jagdish Bhati, B.S. 1968, U.P. Agricultural University; M.S. 1972, University of Agriculture and Technology; M. Phil. 1975, Himachal Pradesh University; Ph.D., University of Hawaii, "Population, Resource Use and Ecological Stresses in the Western Himalayas: An Integrated Strategy for Hill Area Development."

Alfred L. Birch, B.S. 1970, University of British Columbia; M.S. 1975, University of Alberta; Ph.D., Michigan State University, "Off-Site Benefits from Soil Conservation: A Methodological and Distributional Investigation."

Christopher O. Obiechina, B.S. 1971, University of Nigeria; M.S. 1976, University of Manitoba; Ph.D., Oklahoma State University, "Economic and Environmental Impacts of Coal Mining in Eastern Oklahoma."

Luis Ernesto Perez, B.S. 1970, Texas A&M University; Ph.D., North Carolina State University, "The Role of Information, Human Capital, Research and Extension in the Allocation of Resources to Pest Control in Food Production."

Food and Consumer Economics

Carole F. Bitter, B.A. 1967, Case Western Reserve University; M.B.A. 1974, Northeastern University; Ph.D., Cornell University, "Electronic Funds Transfer Systems in the Retail Industries: Past, Present, and Future."

Michael P. Demousis, B.S. 1976, Athens School of Economics and Business Science; M.E. 1978, Ph.D., North Carolina State University, "The Demand for Food at Home, Food Away from Home and Labor Supply."

Stanley McCaull Fletcher, B.S. 1973, M.S. 1975, Oklahoma State University; Ph.D., North Carolina State University, "Economic Implications of Changing Household Food Expenditure Patterns."

Henry William Kinnucan, B.S. 1975, University of Illinois; M.S. 1978, Ph.D., University of Minnesota, "The Role of Income Variability in the Analysis of Household Savings Behavior."

Menwouyellet Moussie, B.B.A. 1972, Haile Selassie University, Ethiopia; M.A.M.R.D. 1978, Ph.D., University of Florida, "Impact of Socioeconomic Characteristics on the Nutritional Status of Adolescents from Low-Income Households in Florida."

Jonathan S. Perry, B.S. 1976, Davidson College; Ph.D., University of Florida, "An Econometric Analysis of Socioeconomic and Demographic Determinants of Fish and Shellfish Consumption in the United States."

John A. Strauss, B.A. 1973, Northwestern University; M.P.A. 1976, University of Minnesota; Ph.D., Michigan State University, "Determinants of Food Consumption in Rural Sierra Leone: Estimation of a Household-Firm Model with Application of the Quadratic Expenditure System."

Human Resource Development

Joan John Daouli, B.S. 1976, Athens School of Economics and Business Science; M.E. 1978, Ph.D., North Carolina State University, "Market for Veterinarian Demand Determinant and Supply Adjustment."

Christine Rugaard Heaton, B.S. 1973, University of Santa Clara; M.S. 1976, Ph.D., University of California, Davis, "Labor Force Behavior of Women in Nonmetropolitan Labor Markets."

Menwouyellet Moussie, B.B.A. 1972, Haile Selassie University, Ethiopia; M.A.M.R.D. 1978, Ph.D., University of Florida, "Impact of Socioeconomic Characteristics on the Nutritional Status of Adolescents from Low-Income Households in Florida."

Industrial Organization; Market Structure

Robert M. Behr, B.P.A. 1976, University of Arizona; Ph.D., University of Florida, "A Simultaneous Equation Model of Futures Market Trading Activity."

Larry G. Hamm, B.S. 1969, Pennsylvania State University; M.S. 1972, University of Wisconsin; Ph.D., Michigan State University, "Food Distributor Procurement Practices: Their Implications for Food System Structure and Coordination."

Tso-Kwei Peng, B.S. 1970, M.S. 1973, National Chung-Hsing University; Ph.D., University of Illinois, "A Simulation Analysis of a Buffer Fund Scheme for Hogs in Taiwan."

Institutions, Private and Public

Carlisle F. Runge, B.A. 1974, University of North Carolina; M.A. 1980, Ph.D., University of Wisconsin, "Institutions and Common Property Externalities: The Assurance Problem in Economic Development."

Gregg Scott, B.A. 1969, University of Notre Dame; B.A. 1974, University of Oxford; Ph.D., University of Wisconsin, "Potato Production and Marketing in Central Peru."

Marketing and Location

Vincent Akinyosoye, B.S. 1970, M.S. 1976, University of Ibadan; M.A. 1980, Ph.D., University of Wisconsin, "Theory of Competitive Pricing and Storage under Uncertainty with Application to Soybeans."

Luis A. Ampuero-Ramos, B.S. 1972, Utah State University; M.S. 1979, Ph.D., Iowa State University, "The Bolivian Beef Cattle Industry: Effects of Transportation Projects upon Plant Location and Product Flows in Beni."

Douglas A. Barnett, B.S. 1976, University of California; M.S. 1979, Ph.D., Purdue University, "A Study of the Effects of U.S. Port Capacity Constraints on National and World Grain Shipments."

Samm Bbuyemosoke, B.A. 1974, M.S. 1975, Makerere University, Uganda; M.A. 1977, Ph.D., Washington State University, "The Supply of and Demand for Asparagus in the United States."

Richard P. Beilock, B.A. 1971, University of Colorado; M.S. 1978, Ph.D., Pennsylvania State University, "A Structural Model and Simulations of the U.S. Potato Industry with Special Emphasis on Examining the Interregional Effects of Changing Energy Costs."

Neilson Chase Conklin, B.A. 1975, Castleton State College; M.S. 1977, University of Wyoming; Ph.D., University of Minnesota, "An Economic Analysis of the Pricing Efficiency and Market Organization of the U.S. Grain Export System."

Alan B. Gossard, B.S. 1973, M.S. 1975, Purdue University; Ph.D., Cornell University, "A Microcomputer-Base Program for Developing Farm Level Marketing Strategies for Corn."

James Michael Harris, B.S. 1969, M.S. 1975, Auburn University; Ph.D., University of Illinois, "The Impact of Unit Train Rates upon Spatial Price Differentials for Corn."

Luiz J. M. Irias, B.S. 1967, M.S. 1969, Federal University, Vicosa, Brazil; Ph.D., University of Florida, "An Econometric Model of International Trade of Frozen Concentrated Orange Juice."

David L. Kendall, B.A. 1975, M.E. 1977, Ph.D., North Carolina State University, "Intertemporal Price Relationships in Non-Inventory Futures Markets."

Corbet J. Lamkin, B.B.A. 1975, Southern State College; M.S. 1979, University of Arkansas; Ph.D., Mississippi State University, "Optimum Cotton Marketing Structure for the Southeastern United States."

Fausto Medina-Lopez, B.S. 1975, Universidad Nacional Autonoma de Honduras; M.S. 1978, Ph.D., University of Illinois, "Selection of the Optimum Size and Location of a Soybean Processing Plant in Puerto Rico."

Ray Dean Nelson, B.A. 1975, Brigham Young University; M.A. 1978, M.S. 1978, Ph.D., University of California, Berkeley, "Should Commercial Grain Farmers Use Futures Markets to Hedge against Price Risk?"

Mechel Shaw Paggi, B.B.A. 1972, University of Texas; M.S. 1975, North Texas State University; Ph.D., Texas A&M University, "An Econometric Evaluation of Investment to Improve the Efficiency of the Export Grain Intermodal Transfer System: Port of Houston."

Greg Scott, B.A. 1969, University of Notre Dame; B.A. 1974, University of Oxford; Ph.D., University of Wisconsin, "Potato Production and Marketing in Central Peru."

Gary L. Smith, B.S. 1970, University of Western

Australia; M.S. 1978, Ph.D., Purdue University, "The Impact of the Accession of Greece, Spain and Portugal to the European Communities on Import Demand for Grains and Oilseeds."

V. Roy Southworth, B.A. 1971, University of Washington; A.M. 1976, Ph.D., Stanford University, "Food Crop Marketing in Atebu District, Ghana."

Wisut Wangworawut, B.S. 1967, Kasetsart University; M.S. 1974, Ph.D., Iowa State University, "Modeling the Japanese Feed Grain Market."

Gary W. Williams, B.S. 1974, Brigham Young University; M.S. 1977, Ph.D., Purdue University, "The U.S. and World Oilseeds and Derivatives Markets: Economic Structure and Policy Interventions."

Natural Resource Economics

Glen D. Anderson, B.A. 1977, University of Washington; M.A. 1979, Ph.D., University of Wisconsin, "An Evaluation of Future Agricultural Land Adequacy."

Charles Barnard, B.S. 1972, M.S. 1976, Montana State University; Ph.D., Washington State University, "The Urban Fringe Land Market: A Contributor to Discontiguous Urban Growth."

Christopher N. Carter, B.S. 1966, University of California, Berkeley; M.B.A. 1968, Ph.D., Oregon State University, "Multi-Fishery Activity in Oregon Commercial Fishing Fleets: An Economic Analysis of Short-Run Decision-Making Behavior."

Dorothy A. Comer, B.S. 1974, M.S. 1977, New Mexico State University; Ph.D., University of Nebraska, "An Economic Analysis of Ground Water Management Alternatives."

Burton C. English, B.S. 1974, Iowa State University; M.S. 1976, New Mexico State University; Ph.D., Iowa State University, "Long-Term Impacts of Soil Erosion: A National and Interregional Analysis for the Year 2030."

Susan S. Hanna, B.S. 1966, M.S. 1977, University of Maine; Ph.D., Oregon State University, "A Theoretical Analysis of Information Networks in the Fishery."

Daniel Conrad Hardin, B.S. 1973, M.S. 1975, Ph.D., Oklahoma State University, "Break-Even Investment in a Wind Energy Conversion System for an Irrigated Farm on the Texas High Plains."

Girmai Ibrahim, B.S. 1970, Haile Selassi University; M.S. 1972, Ph.D., Ohio State University, "Crop Production, Soil Erosion and the Environment in the Maumee River Basin—A Modelling Approach."

Gary V. Johnson, B.S. 1970, M.S. 1976, M.A. 1978, Ph.D., University of Wisconsin, "The Firm, the Fishery, and Public Decisions: An Analysis of Wisconsin's Lake Michigan Chub Fishery."

Ruth Crumley Johnson, B.S. 1970, M.S. 1971, Ph.D., University of Tennessee, "Housing Market Capitalization of Energy-Saving Durable Good Investments."

Muin Salem Kakish, B.S. 1974, M.S. 1976, Utah State University; Ph.D., Ohio State University, "Economic Impacts of Changes in Coal and Other Industrial Developments: A Regional and County Input-Output Analysis."

Gunnar Knapp, B.A. 1975, M.A., M. Phil., Ph.D., Yale University, "The Supply of Timber from Nonindustrial Private Forests."

James Arley Larson, B.S. 1973, M.S. 1975, New Mexico State University; Ph.D., University of Nebraska, "An Economic Analysis of Alternative Irrigation Scheduling Methods."

William Franklin Lazarus, B.S. 1973, M.S. 1978, Pennsylvania State University; Ph.D., University of Illinois, "Optimal Management of a Common Property Pest under Risk: An Application to the Corn Rootworm."

Kun Chol Lee, B.S. 1970, Kyoto University, Japan; M.A. 1973, Seoul National University; M.A. 1979, State University of New York at Stony Brook; Ph.D., Iowa State University, "Optimal Exploitation of Common Property Resources: A Case of Groundwater Mining in the Ogallala Aquifer."

Arlen Leholm, B.S. 1970, M.S. 1972, North Dakota State University; Ph.D., University of Nebraska, "Potential Impact of Ground Water Policy Alternatives on Nebraska Agriculture, 1977–2020."

Jay Andrew Leitch, B.A. 1974, Moorhead State University; M.S. 1976, North Dakota State University; Ph.D., University of Minnesota, "Valuation of Prairie Wetlands."

Kerry Rayford Livengood, B.S. 1974, M.S. 1976, University of Tennessee; Ph.D., Texas A&M University, "A Comparison of Market and Non-Market Methods of Estimating the Demand for and Benefits of Outdoor Recreation."

Dinesh K. Marothia, B.S. 1969, J. N. Agricultural University; M.S. 1971, G.B. Pant University; Ph.D., University of Alberta, "An Economic and Institutional Analysis of Soil Erosion on Agricultural Land."

Anunt Mutarais, B.S. 1972, M.S. 1974, Bangladesh Agricultural University; Ph.D., Iowa State University, "Measuring and Factors Affecting the Risk Attitude of Selected Iowa Farmers."

Glenn Okimoto, B.S. 1975, M.S. 1978, Ph.D., University of Hawaii, "Optimal Control for Land Use Decisions in Hawaii: Model Formulation and Potential Applicability."

James Joseph Opaluch, A.B. 1975, University of Rhode Island; M.A. 1977, Ph.D., University of California, Berkeley, "River Basin Management: The Optimal Control of Water Quantity and Quality."

James S. Shortle, B. of Univ. Studies 1976, M.A. 1978, University of New Mexico; Ph.D., Iowa State University, "Soil Erosion and Water Quality: A Study in the Optimal Conjunctive Management of Natural Resources."

Colin N. Sorhus, B.A. 1974, Brigham Young University; Ph.D., Oregon State University, "Estimated Expenditures by Sport Anglers and Net Economic Values of Salmon and Steelhead for Specified Fisheries in the Pacific Northwest."

William Franklin Watson, B.A. 1971, M.E. 1974, Ph.D., North Carolina State University, "Policy Analysis of Incremental Cost Pricing of Industrial End-Use of Natural Gas."

William B. White, B.A. 1972, Wake Forest University; M.S. 1977, University of Idaho; Ph.D., Oregon State University, "Valuation of Recreation Resources: Methodological Comparison as Applied to Steens Mountain, Oregon."

Wilbert Wong, B.S. 1976, M.S. 1977, M.S. 1980, Ph.D., University of Hawaii, "A Dynamic Land Potential Assessment System."

Production Economics and Management

Mohammad Ashraf, B.S. 1967, M.S. 1969, West Pakistan Agricultural University; Ph.D., University of Hawaii, "An Analysis of Some Sectors Affecting Technology Adoption: A Case Study of Fertilizer Use in the Indus Basin, Pakistan."

Marvin Thomas Batte, B.S. 1975, Eastern Kentucky University; M.S. 1978, University of Kentucky; Ph.D., University of Illinois, "An Analysis of Scale Economics on Commercial Illinois Cash Grain Farms."

Binayak P. Bhadra, B. Tech. 1971, Indian Institute of Technology; Post Grad. Dipl. in Econ. Development 1973, Victoria University of Manchester; Ph.D., Oregon State University, "Separability Tests on Wheat Production Functions in Oregon."

Hao Chun Chang, B.S. 1970, National Taiwan University; M.S. 1975, Montana State University; Ph.D., Texas A&M University, "An Econometric Analysis of the Citrus Industry and Estimated Impacts of Withdrawing Selected Pesticides."

Gerald Charles Cornforth, B.S. 1973, Oklahoma State University; M.S. 1976, Ph.D., Texas A&M University, "Economic Implications of Farmer Storage of Surface Irrigation Water in Federal Projects: El Paso County, Texas."

Michael D. Duffy, B.S. 1975, M.S. 1977, University of Nebraska; Ph.D., Pennsylvania State University, "Mushroom Integrated Pest Management and the Cost of Current Management Techniques."

Saad El-Shereif, B.S. 1968, M.S. 1975, Cairo University; Ph.D., University of Missouri, "Statistical Analysis of the Impact of Technical and Economic Factors of Crop Yield."

Art Greer, B.S. 1966, M.S. 1968, Colorado State University; Ph.D., University of Nebraska, "A Computerized Farm Liquidation Planning Model."

Gregory Dean Hanson, B.A. 1972, Dartmouth College; M.S. 1978, Ph.D., University of Minnesota, "Agricultural Income Tax Expenditures and Their Effects on Farm Growth."

Thomas R. Harris, B.B.A. 1970, University of Texas; M.S. 1972, Texas Tech University; Ph.D., Oklahoma State University, "Analysis of Irrigation Scheduling for Grain Sorghum in the Oklahoma Panhandle."

Nasrin Hendissi, B.B.A. 1973, M.A. 1974, University of Miami; M.A. 1978, Ph.D., University of Wisconsin, "Wheat Producers' Response to Government Policies: The Case of Spain, 1957-1977."

Roger L. Hoskin, B.S. 1971, University of Akron; M.A. 1972, Western Michigan University; Ph.D., Michigan State University, "An Economic Analysis of Alternative Saginaw Valley Crop Rotations: An Application of Stochastic Dominance Theory."

David L. Hunter, B.S. 1968, Berea College; M.S. 1969, Purdue University; Ph.D., University of Tennessee, "Economic Evaluation of Alternative Crop Management Systems for Reducing Soil Erosion Losses on West Tennessee Farms."

Robert Ken Lindner, B. Ag. Sc. 1964, B.Ec. 1967; M.S. 1968, University of Adelaide; Ph.D., University of Minnesota, "Adoption as a Decision-Theoretic Process."

Mohd. Ghazali Mohayidin, B.S. 1973, Louisiana State University; M.S. 1974, Oklahoma State University; Ph.D., University of Hawaii, "Risk in Farm Decision Making: A Case of Crop Selection in Two Malaysian Districts."

Basilio Nikiphoroff, Graduate 1972, National University of Asuncion, Paraguay; M.S. 1979, Ph.D., University of California, Davis, "Economic Analysis of Paraguayan Farms under Uncertainty."

Thomas L. Nordblom, B.S. 1969, California State Polytechnic University; M.S. 1971, Ph.D., Oregon State University, "Simulation of Cattle Cycle Demography: Cohort Analysis of Recruitment and Culling Decisions in the National Beef Cow Herd."

Russell C. Parker, B.S. 1972, University of Maine; M.S. 1974, Michigan State University; Ph.D., University of Tennessee, "Size Optimization of Dairy Manure Storage."

Tillak Persaud, B.S. 1973, University of Illinois; M.S. 1976, University of Idaho; Ph.D., Oklahoma State University, "Decision Making Relating to Risk Management Strategies in a Farm Planning Model."

Ronald Lee Plain, B.S. 1974, M.Ed. 1976, University of Missouri; Ph.D., Oklahoma State University, "Adaptive Planning under Price Uncertainty in Swine Production."

Clive A. Pope, B.S. 1978, Brigham Young University; M.S. 1980, Ph.D., Iowa State University, "The Dynamics of Crop Yields in the U.S. Corn Belt as Affected by Weather and Technological Progress."

Milton E. Rister, B.S. 1974, M.S. 1976, Texas A&M University; Ph.D., Michigan State University, "IFLMAPS: An Interactive Farm Level Marketing and Production Simulator Intended for Research, Teaching and Extension Applications."

Ahmad Rostamizadeh, B.A. 1971, Tehran University, Iran; M.A. 1977, University of Southern California; Ph.D., Washington State University, "Duality between Cost and Production Functions with

Application to the Agricultural Labor Markets in the United States, Washington State, and California."

Athanasios H. Stamatiou, B.S. 1968, Agricultural University of Athens; Ph.D., Iowa State University, "Interregional Competition and Adjustments in Hog Production: A Spatial Analysis to Determine the Optimal Location and Structure of Hog Production."

Yuavares Gaesuwan Tubpun, B.A. 1971, M.A. 1973, Thammasat University; Ph.D., University of Minnesota, "Economics of Tank Irrigation Projects in Northeastern Thailand."

Wilbert Wong, B.S. 1976, M.S. 1977, M.S. 1980, Ph.D., University of Hawaii, "A Dynamic Land Potential Assessment System."

Anthony Yeboah, B.S. 1975, University of Science and Technology, Ghana; M.S. 1978, Ph.D., Iowa State University, "A Study of the U.S. Hog Industry."

Public Policy

Robert L. Bancroft, B.S. 1974, M.S., University of Vermont; Ph.D., Purdue University, "An Econometric Analysis of Aggregate Acreage Response, Program Participation and Retirement."

Dorothy A. Comer, B.S. 1974, M.S. 1977, New Mexico State University; Ph.D., University of Nebraska, "An Economic Analysis of Ground Water Management Alternatives."

Mark A. Edleman, B.S. 1975, M.S. 1978, Kansas State University; Ph.D., Purdue University, "Alternative Farm Commodity Program Options for the Eighties: An Analysis of Economic Implications with Emphasis on Growth of Indiana Crop Farms."

Jaime A. M. Gardea, B.S. 1970, National School of Agriculture; M.S. 1975, Graduate School Escuada de Agriculture; Ph.D., Purdue University, "Trade Policy and Some Aspects of the Distribution of Income in Agriculture: Mexico."

Nathan M. Garren, A.B. 1974, J.D. 1977, Ph.D., University of Georgia, "The Efficient Allocation of Agricultural Research Investment with Externality Considerations."

Kisan R. Gunjal, B.S. 1971, College of Agriculture, Poona, India; M.S. 1975, Indian Agricultural Research Institute; Ph.D., Iowa State University, "Economic Analysis of Farm Machinery Investment and Simulations under Alternative Energy, Price Support, and Export Policies."

Kenneth F. Harling, B.S. 1973, University of Guelph; M.S. 1976, Ph.D., Purdue University, "An International Comparison of Agricultural Policy: Canada, the Federal Republic of Germany, and the United Kingdom."

David R. Lee, B.A. 1972, Amherst College; M.A. 1980, Ph.D., University of Wisconsin, "Acreage Allocation under Changing Government Feedgrain Programs."

Arlen Leholm, B.S. 1970, M.S. 1972, North Dakota State University; Ph.D., University of Nebraska, "Potential Impact of Ground Water Policy Alternatives on Nebraska Agriculture, 1977-2020."

Ramesh Bahadur Munankami, B.S. 1966, M.S. 1968, University of Allahabad; M.S. 1977, Ph.D., University of Missouri, "Issues and Attitudes Relative to the Organizational Structure of U.S. Agriculture with Special Reference to Missouri Farmers."

Doug Nelson, B.S. 1968, J.D. 1971, Ph.D., University of Nebraska, "A Legal-Economic Critique of Ground Water Law and Administration."

Glenn Okimoto, B.S. 1975, M.S. 1978, Ph.D., University of Hawaii, "Optimal Control for Land Use Decisions in Hawaii: Model Formulation and Potential Applicability."

Gregg L. Parvin, B.S. 1974, Arkansas Tech University; M.S. 1977, University of Arkansas; Ph.D., Oklahoma State University, "An Application of Optimal Control Methods to Agricultural Policy Analysis and Formulation."

Francisco J. Proenza, B.A. 1969, Ph.D., University of Florida, "Impact of the Supervised Credit System on the Use of Modern Agricultural Practices: The Case of Corn in Guatemala."

Norberto A. Salecedo Quezada, B.S. 1972, Inqueniero Agronomy Catholic University; M.S. 1973, University of California; Ph.D., Purdue University, "Endogenous Agricultural Price and Trade Policy in the Dominican Republic."

Jerry R. Skees, B.A. 1975, M.S. 1977, University of Kentucky; Ph.D., Michigan State University, "A Multiple Farm Simulation Model of the Impact of Income Tax and Commodity Policies on the Opportunities for Growth of Varied Size Corn/Soybean Farms."

Cameron Scott Thraen, B.S. 1972, Northern State College; M.S. 1974, South Dakota State University; Ph.D., University of Minnesota, "An Econometric Assessment of the U.S. Dairy Price Support Policy with Special Emphasis on Risk, Uncertainty and Rational Producer Expectations."

Gerrit C. VanKooten, B.S. 1972, M.A. 1974, University of Alberta; Ph.D., Oregon State University, "The Integration of Efficiency and Equity in Public Decision Making: Theoretical Issues and Applications."

Hilda Yumiseva, B.A. 1970, Pitzer College; Ph.D., University of Florida, "Agricultural Policy: A Linear Programming Application to Guatemala."

Rod F. Ziemer, B.B.A. 1974, Augusta College; M.S. 1977, Ph.D., University of Georgia, "Disequilibrium in Agricultural Markets: The U.S. Beef Sector."

Regional, Rural, and Community Development

Charles Barnard, B.S. 1972, M.S. 1976, Montana State University; Ph.D., Washington State University, "The Urban Fringe Land Market: A Contributor to Discontiguous Urban Growth."

Caryl Ruppert Ersenkal, B.A. 1971, Manhattanville College; M.U.P. 1975, New York University; Ph.D., Clemson University, "The Product Cycle in Regional Growth: An Application to South Carolina."

Terence Sherrod, B.A. 1973, Eastern Washington State College; Ph.D., Washington State University, "The Impacts of Farm Size on the Economic Development of a Regional Economy."

Ghodratola Simnegar, B.S. 1974, Pahlavi University, Iran; M.S. 1977, Ph.D., Utah State University, "The Effect of Zoning on the Price of Single-Family Homes: An Empirical Study."

Phillip R. Wandschneider, B.A. 1969, Occidental College; M.A. 1977, Ph.D., Michigan State University, "The Political Economy of Regional Planning Organizations in Michigan."

Research Methodology

Kesiena Oghenemado Agori-Iwe, B.A. 1972, Howard University; M.S. 1975, Purdue University; Ph.D., University of Illinois, "Integer Programming Heuristics for Large Capital Budgeting Problems."

Daniel Otto, B.S. 1976, M.S. 1978, University of Minnesota; Ph.D., Virginia Polytechnic Institute and State University, "An Economic Assessment of Research and Extension Investment in Corn, Wheat, Soybeans, and Sorghum."

James Standaert, A.B. 1973, Gonzaga University; M.A. 1979, Ph.D., Washington State University, "A Comparison of Alternative Forecasting Methods: Econometric versus ARIMA."

William B. White, B.A. 1972, Wake Forest University; M.S. 1977, University of Idaho; Ph.D., Oregon State University, "Valuation of Recreation Resources: Methodological Comparison as Applied to Steens Mountain, Oregon."

Sector and Subsector Analysis

Richard Douglas, B.A. 1973, Howard University; M.S. 1976, Ph.D., University of Maryland, "The Energy Intensiveness of Maryland's Agricultural Sector and Economic Implications of Increases in Energy Prices on Maryland's Agricultural Output."

Thomas C. Slane, B.S. 1970, Rutgers University; M.S. 1974, University of Massachusetts; Ph.D., Pennsylvania State University, "An Econometric Model for Predicting Monthly Price and Production in the U.S. Egg Subsector."

Socioeconomic Research

Martin Louis Brown, B.S. 1967, San Diego State University; M.S. 1976, Ph.D., University of California, Berkeley, "A Historical Economic Analysis of the Wage Structure of the California Fruit and Vegetable Canning Industry."

Taxes, Taxation, and Rural Appraisal

Boris Bravo-Ureta, B.S. 1975, M.S. 1977, University of Wisconsin, River Falls; Ph.D., University of Nebraska, "The Impact of Selected Tax Provisions on Farm Growth and Structure.

James Francis Dunne, B.A. 1972, University of Massachusetts; M.S. 1976, Boston College; Ph.D., Cornell University, "Estimating the Use Value of Agricultural Land for Farm Assessments in New York State."

Technological Change

Salahuddin Ahmad, Ph.D., Yale University, "Output and Factor Market Effects of Technological Progress, Population Investment in Bangladesh Agriculture."

Mohammad Ashraf, B.S. 1967, M.S. 1969, West Pakistan Agricultural University; Ph.D., University of Hawaii, "An Analysis of Some Sectors Affecting Technology Adoption: A Case Study of Fertilizer Use in the Indus Basin, Pakistan."

Richard Douglas, B.A. 1973, Howard University; M.S. 1976, Ph.D., University of Maryland, "The Energy Intensiveness of Maryland's Agricultural Sector and Economic Implications of Increases in Energy Prices on Maryland's Agricultural Output."

A. Steven Englander, B.A. 1975, McGill University; M.A. 1976, Ph.D., Yale University, "Technology Transfer and Development in Agricultural Research Programs."

Nathan M. Garren, A.B. 1974, J.D. 1977, Ph.D., University of Georgia, "The Efficient Allocation of Agricultural Research Investment with Externality Considerations."

Trade

Luis Miguel Albisu, Ing. Agr. 1971, E.P.T. Ingenieros Agronomos, Madrid, Spain; M.S.C. 1973, University of New Castle; Ph.D., Cornell University, "Analysis of Supply, Trade and Prices for Oranges and Mandarins in the Mediterranean Area."

Luis J. M. Irias, B.S. 1967, M.S. 1969, Federal University, Viscosa, Brazil; Ph.D., University of Florida, "An Econometric Model of International Trade of Frozen Concentrated Orange Juice."

Tipaporn Lokaphadhana, B.Econ. 1974, Chulalongkorn University; M. Econ. 1976, Thammasat University; Ph.D., University of Minnesota, "Impact of Trade Policy on Six Agricultural Exports of Thailand."

Daniel T. Norton, B.A. 1974, University of Melbourne; M.E. 1977, University of New England; Ph.D., North Carolina State University, "Institutional Intervention in the Market for an Internationally Traded Commodity: U.S. Flue Cured Tobacco."

Maria L. Paez, B.S. 1965, Pontificate Catholic University of Sao Paulo; M.S. 1967, University of Sao Paulo; Ph.D., Oregon State University, "An Economic Analysis of Some Factors Associated with the International Trade Flows of Frozen Groundfish Blocks."

Other Futures Markets

Robert M. Behr, B.P.A. 1976, University of Arizona; Ph.D., University of Florida, "A Simultaneous Equation Model of Futures Market Trading Activity."

Seafood

Jonathan S. Perry, B.S. 1976, Davidson College; Ph.D., University of Florida, "An Econometric Analysis of Socioeconomic and Demographic Determinants of Fish and Shellfish Consumption in the United States."

Ph.D. Recipients by Institution, 1981

University of Alberta

Dinesh K. Marothia

University of California, Berkeley

Martin Louis Brown
Mohammad Akram Chowdry
Luis Arturo Crouch
Ray Dean Nelson
James Joseph Opaluch

University of California, Davis

Christine Rugaard Heaton
Richard Robert Henry
Basilio Nikiphoroff
Gustavo Sain

Clemson University

Caryl Ruppert Ersenkal

Cornell University

Luis Miguel Albisu
Carole F. Bitter
Timothy James Considine
James Francis Dunne
Jaime Marcos Fernandez
Alan B. Gossard
Anibal Monares

University of Florida

Robert M. Behr
Luiz J. M. Irias
Menwouyellet Moussie
Jonathan S. Perry
Francisco J. Proenza
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